GEAR TECHNOLOGY

JULY/AUGUST 2004

The Journal of Gear Manufacturing

www.geartechnology.com

GREENER GEARS
- Our Special Look at the Gear Industry and the Environment

IMTS Pre-Show Issue
- 18-page Sneak Preview

FEATURES
- Profile: The Falk Corp.
- Influence of Coatings on Gear Life
- Screw Helicals: Steel Pinions & Plastic Wheels

THE GEAR INDUSTRY'S INFORMATION SOURCE

KEEPING THE WORLD IN MOTION™

IMTS '04 BOOTH #B-6902

The world's gear-producing companies are on the move, and the search is on for the technologies that will give them a competitive advantage.

Many global leaders are finding that the new gear-making solutions they're searching for have never been closer – at Gleason. Today, Gleason stands virtually alone in its ability to deliver a complete array of technologically superior solutions to solve customer challenges anywhere in the world.

You can see many of these products in action at IMTS '04. Machines that produce bevel gears faster and more accurately... hard finish cylindrical gears economically in high volumes... completely inspect gears in less time... all with the service and support to help you take full advantage of these amazing new technologies anywhere in the world.

Combining these new machines with the latest in cutting tools holds the key to driving down cost-per-piece and improving workpiece quality. At Gleason Cutting Tools,

Bevel Gear Production

Bevel Gear Cutting Tools

Cylindrical Gear Production

Workholding Solutions

Full Line of Cutting Tools

IMTS '04 BOOTH #B-6902

new Lean Manufacturing methods and substantial investments in ultra-modern facilities have made it possible to deliver a full line of highly productive new tooling solutions faster and more efficiently than ever before.

Now you can place a shaper cutter order and receive the tool in just four weeks. Get the latest hobs in five weeks. Or take advantage of one of the world's most modern facilities for producing replatable CBN and diamond grinding and dressing wheels and plated diamond rolls.

These and many other advanced tooling solutions, and the latest in workholding, will be on display at IMTS '04.

Where do you want to go next? You'll find the answer at Gleason.

Gleason Corporation

1000 University Ave., P.O. Box 22970
Rochester, NY 14692-2970 U.S.A.
Phone: 585/473-1000 • Fax: 585/461-4348
www.gleason.com • sales@gleason.com

CBN Grinding Wheels

Gear Metrology

Software

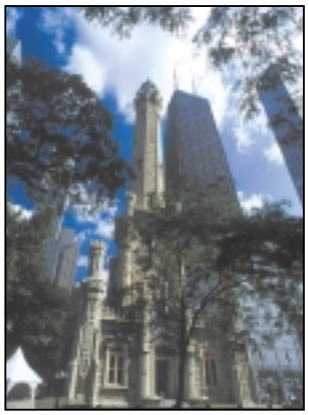
Application Support

Tool Sharpening Services

GEAR TECHNOLOGY

JULY/AUGUST 2004

The Journal of Gear Manufacturing



14

9

32

Greener Gears, p. 32

IMTS PRE-SHOW ISSUE

Show Basics
Everything you need to know about IMTS 2004.....14

IMTS Sneak Preview
An advance look at some of the new products and technology at this year's show.....19

Showstoppers
A special advertising section featuring IMTS exhibitors.....28

FEATURES

Company Profile: The Falk Corp.
How one of the oldest names in gearing got its start.....9

Greener Gears
A series of articles on the gear industry and the environment.....32

Load Carrying Capacity of Screw Helical Gears with Steel Pinions and Plastic Wheels
Research into this important emerging combination.....42

Influence of Coatings and Surface Improvements on the Lifetime of Gears
A study on the effectiveness of gear coatings.....50

DEPARTMENTS

Publisher's Page
Hitting the Sweet Spot.....7

Technical Calendar
Don't miss these upcoming industry events.....49

Product News
New machines, tools and other products for the gear industry.....57

Industry News
The latest news from the gear industry.....59

Classifieds
Services, Heat Treating, Websites, Software and Gear Manufacturing.....61

Advertiser Index
Use this directory to get information fast.....63

Addendum
Gear Décor.....64

KAPP CBN wheels make *any* machine more efficient, more productive, more profitable. Come find out about KAPP CBN tools from our experts at Booth B-6931

IMTS
2004 KAPP Booth B-6931

2870 Wilderness Place
Boulder, Colorado 80301

www.kapp-usa.com

Ph: 303-447-1130
Fx: 303-447-1131

GEAR TECHNOLOGY
The Journal of Gear Manufacturing

EDITORIAL

Publisher & Editor-in-Chief
Michael Goldstein

Managing Editor William R. Stott

Associate Editor Joseph L. Hazelton

Assistant Editor Robin Wright

Editorial Consultant Paul R. Goldstein

Technical Editors
Robert Errichello, Don McVittie
Robert E. Smith, Dan Thurman

ART

Art Director Jean Bartz

ADVERTISING

Advertising Manager Patricia Flam

Advertising Coordinator Carol Tratar

CIRCULATION

Circulation Coordinator Carol Tratar

INTERNET

Web Developer Dan MacKenzie

***Gear Industry Home Page*™ Sales**
Patricia Flam

***powertransmission.com*™ Sales**
Clark Hopkins

RANDALL PUBLISHING STAFF

President Michael Goldstein
Vice President Richard Goldstein
Accounting Luann Harrold

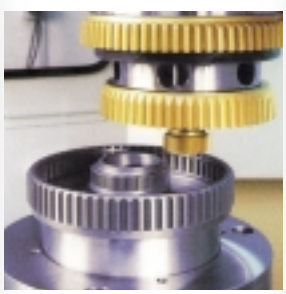
Phone: 847-437-6604
E-mail: *wrs@geartechnology.com*
Web: *www.geartechnology.com*
www.powertransmission.com

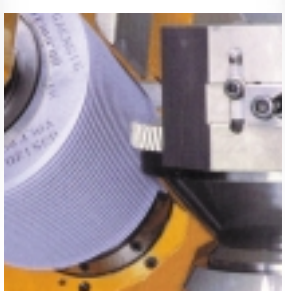
BPA INTERNATIONAL

VOL. 21, NO. 4

GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published bimonthly by Randall Publishing, Inc., 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL 60007, (847) 437-6604. Cover price $5.00 U.S. Periodical postage paid at Arlington Heights, IL, and at additional mailing office (USPS No. 749-290). Randall Publishing makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL, 60007.

No matter how you need your gears machined,
LIEBHERR HAS A WAY!





Liebherr Gear Technology Co.
1465 Woodland Drive
Saline, MI 48176-1259
734.429.7225
Fax 734.429.2294
info@lgt.liebherr.com

SIGMA POOL

The Gearing Partnership of Liebherr, Klingelnberg and Oerlikon

As the pioneer of high-speed dry gear machining, Liebherr is leading the way in gear cutting, offering machines with gear drives or direct drives in modular platforms from 80 mm to 4500 mm diameters.

Hobbing. *Productivity:* fast cycle times over the full spectrum of external gears.

Shaping. *Flexibility:* CNC guide for internal and external spur or helical gears.

Grinding. *Precision:* generating or profile grinding, with dressable or CBN tools in one machine.

Liebherr gear machines are renowned for quality, productivity, reliability, maintainability and low life-cycle cost.

LIEBHERR

Gear Hobbing • Shaping • Grinding • Measuring

THE BEST PRODUCT LINE FOR YOUR

Bottom line

Maximize quality and minimize cost per part produced.

- Cut fine gears down to 254 DP with our **Fine Pitch Micro Hob**. Features premium grade cutting materials.
- Our **Heavy Duty Roughing** (Broach Tooth) **Hobs** feature a deep and shallow tooth geometry with alternating gashes. Increases tool life, feed rates, while reducing hammering effect.
- Our **Expansion Chucks** allow shank style tools to easily adapt to machines with tool changeable arbors.
- Chamfer and deburr on a hobbing machine in one setup - the **Chamfer Cut** requires no secondary operation, reducing manufacturing time, capital expenditures and tooling costs.

Call today for a test trial of our innovative gear cutting solutions.

LMT

LMT-FETTE, INC.
18013 Cleveland Parkway, Suite 180, Cleveland, Ohio 44135
Phone: 800-225-0852 or 216-377-6130 • Fax: 216-377-0787
www.lmtfette.com lmtfette@lmtfette.com

Sweet Spot

When a baseball player hits the ball well, he can hear it and feel it in his swing. There's nothing quite like the feel of driving the bat through the ball and watching the ball sail over the fence. A lot of things have to happen for the batter to make the right connection. He has to see the ball well. The pitch has to be in the right spot. His timing has to be just right. His bat speed has to be high. And all those factors have to combine so that when he hits the ball, it strikes the right part of his bat, the part known as "the sweet spot."

Gear manufacturers may soon have the opportunity to hit a sweet spot of their own. Like the big league slugger, gear manufacturers need a lot of things to go right in order to hit the sweet spot, but it looks to me like everything may be coming together—just in time for IMTS.

America's industrial economy has been growing all year. Most gear manufacturers I talk to are extremely busy these days. Today, getting steel seems to be more of a problem than getting customers. The cutting tool suppliers I talk to are also extremely busy, although tool pricing pressure is still high. Many gear machine tool suppliers are quoting on new projects like crazy, but some are still waiting for the flood of orders to come in.

There's a lot of good activity in the gear industry, and now may be the right time for you to take advantage of it. With the intense pressure on the machine tool manufacturers right now, there are deals to be made. They want and need your business.

But if you need extra productivity or capacity, you'd better act fast, since there is very little gear equipment readily available or coming available shortly. It doesn't take long for the machine tool manufacturers' order books for near-term delivery to get filled, so what's out there is disappearing fast. You can't just double production of gear hobbers, grinders or any complex machine tool overnight. Right now, you may still be able to get a machine that's in stock, or one that's in the pipeline but not yet spoken for. For those who are thinking of buying machine tools, it may not yet be the bottom of the ninth, but time is running out.

IMTS provides a prime opportunity to see and evaluate most all of your options under one roof. Most of the major gear industry suppliers will be located in one place—the gear pavilion—and many of them are introducing new technology at the show (see our pre-show coverage beginning on page 14).

But even if your company isn't ready to spend money on new equipment, you should attend the show to familiarize yourself with what's out there and its availability. There's no better time to compare the products of the various manufacturers. The booths are usually loaded with a wide range of gear knowledge and experience. The people who design, build, sell, install and service this equipment will all be available. Now's your chance to ask questions about the technology and find out the situation regarding delivery times.

In baseball, hitters know that not every pitch can be hit out of the park. But the best ones are ready when the right pitch comes. Like them, you need to be ready for that pitch. Lately, for many of us in the gear industry, the pitches are starting to look like softballs.

We'll be exhibiting in the gear pavilion in booth B-7113. We hope to see you at the show.

NEED TO CHECK GEARS?

Check Marposs For All The Gear You Need

Looking for an easy, cost-effective way to check gears? Marposs has the solution – the M62 bench gauge system. It's accurate, flexible and right at home on the shop floor.

No more dedicated gauges
The modular M62 system is quickly re-toolable using ordinary hand tools. You'll save time and the cost of dedicated gauges.

A single-source for all of your gear inspection needs
No one has a more complete line of gear checking equipment than Marposs, so every component is guaranteed compatible. Forget mixing and matching.

If you are looking for easier, more accurate gear checking plus optional noise detection, take a look at the Marposs M62 bench gauge system. It's geared just for you.

M62 Double Flank Gear Roller
Manual loading of gear wheels and gear shafts

Measures:
- Radial composite deviation
- Radial runout
- Tooth to tooth radial composite deviation
- Tangential composite deviation
- Nicks
- Optional measurements include center distance, bore diameter and perpendicularity of bore to gear face
- Optional noise detection

All functional checks can be displayed on the rugged E9066 industrial PC system which offers a linear graphic display with full SPC functions

M62 OBD Gear Gauge
OBD, PD and root diameter inspection ■
Re-toolable ■
Multiple standard capabilities ■
Ball or pin contacts ■
Shaft and ring-type parts ■
Manual gear rollers ■
Manual or automatic operation ■
Statistical packages available ■

Gear Masters/Gauges
- Go-no go gauges
- Thread gauges
- Spline gauges
- Plain masters and master gears

MARPOSS

3300 Cross Creek Parkway
Auburn Hills, MI 48326-2758
1-888-627-7677
Fax: 248-370-0621
E-mail: marposs@us.marposs.com
www.marposs.com

A Winding Path into the Gear Industry: The Falk Corp.

Joseph L. Hazelton

Glancing back now, The Falk Corp. looks to have had a straight path toward power transmission when it opened in 1892.

That year, Herman Falk's business started by making couplings for wagons. The couplings joined a horse-drawn wagon's shaft to its axle.

Today, The Falk Corp. makes geared and coupling products for medium- and heavy-duty industrial applications. Moreover, it's a leading manufacturer of gears, especially heavy-duty industrial gears.

Worldwide, Falk employs more than 1,000 people and has more than 1.8 million square feet of manufacturing space in seven factories and four distribution centers.

Far from taking a straight path, though, Herman and his company spent years venturing into various industries to find a profitable place for themselves in the manufacturing world.

Wagon Couplings Not Enough

To start with, the wagon coupling business alone wasn't enough to support Herman's company.

So, in 1894, he expanded his company into a general-purpose machine shop. His new shop led him back to his father's old brewery site in Milwaukee's Menomonee Valley.

Beer Before Gears—Herman Falk founded The Falk Corp. with money from selling his share of the Milwaukee brewery business created by his late father, Franz Falk.

Falk's Uncommon Ability

A ring gear 43 feet in diameter made to AGMA quality level Q10 and used to crush copper ore from a Chilean mine. Fifteen bull gears, with 4.5-meter diameters and tip and root modifications, made to Q12 for 33,000 hp marine drives in U.S. Navy ships.

These are examples of The Falk Corp.'s most significant, uncommon ability: the manufacture of large, high accuracy, modified gears. Falk can hob and grind gears up to four meters in diameter, as well as make lead and profile modifications to gears up to that size. It can also shape gears up to 14 meters in diameter.

Falk's ability comes from its 12 large hobbers, shapers and grinders. The hobbers include a Schiess machine with a 5-meter table and a Pfauter machine with a 3-meter table. Large ring gears are cut with a 14-meter Maag machine and a Maag SH600 shaper. The grinders include a 4-meter Höfler Maxima 4000, a Höfler 1600 and a Pfauter 1250.

The ability also comes from Falk's in-house foundry. Beyond its machines' limits, Falk turns to its foundry, where gears up to 15 meters in diameter can be cast.

Falk's foundry operation takes up about 10% of the Milwaukee factory's 1.1 million square feet, pouring molten metal for Falk's large gears and couplings (hubs).

"We're only pouring the rotating elements," says Craig Danecki, Falk's engineering director.

Still, he estimates about 20% of Falk products start in the foundry and adds about Falk's ability: "Not everyone can do the large pieces."

In 1856, Herman's father, Franz Falk, had co-founded a brewery on the outskirts of Milwaukee, Wisconsin.

Decades later, after Franz's death, Herman and his three brothers sold their interests in their father's brewery to Captain Fred Pabst of Pabst Brewing.

As a Pabst shareholder, Herman probably could have joined his brothers in the larger company, but he decided to use his money and mechanical ability to create his own business.

In 1894, Herman rented an old blacksmith shop, a narrow brick building on the Menomonee River, and opened his new shop. He still worked on wagons, but he also shod horses and made stage machinery for the Pabst Theater (Fred Pabst's performing arts center).

Falk: A Railway Company

Soon, Herman was focusing his business on a new technology, electrified transportation. Specifically, he turned his attention to manufacturing the joints between streetcar rails.

The joints suffered constant pounding from the heavy cars, so the rail ends wore down a lot faster than the rails themselves. Herman and Albert Hoffmann, a Milwaukee electrician and inventor, developed a process called cast welding.

"The heart of their system was, in essence, a foundry on wheels," says John Gurda, a Milwaukee historian who wrote a company history for Falk in 1992 to commemorate its first 100 years.

According to Gurda, no one had previously applied the casting process to rail joints, and the process was soon hailed as a breakthrough.

In 1896, Herman diversified his company by creating a special work department, which manufactured different types of joints for railroads, including switches, crossings, and X-shaped "frogs" to use where rails curved, crossed, or converged.

Herman next tried to turn Falk into a company for building and equipping complete railway systems, including tracks, ties, posts and wires. But giants General Electric and Westinghouse were strengthening their holds on transit technology.

So Herman took his business in another direction.

Falk: An Electric Company

In 1899, his company became involved in power transmission—*electrical* power transmission—and bought Cloos Engineering Co. A small shop, Cloos specialized in electric lighting and power transmission.

Falk also bought a gear cutting shop, Western Gear Co. (not to be confused with Falk's recent competitor).

Falk: A Gear Company?

In 1899, the Falk business included cast-welding equipment, special track work, street railway construction, oil switches, and motor gears and pinions.

Now the business faced a space shortage, so Herman bought more than four acres in the Menomonee Valley, just north of Falk's shops.

In 1899, construction started on Falk's new 70,000-square-foot factory. It was completed in 1900. After that year, the company moved away from street railways, cast welding and general contracting.

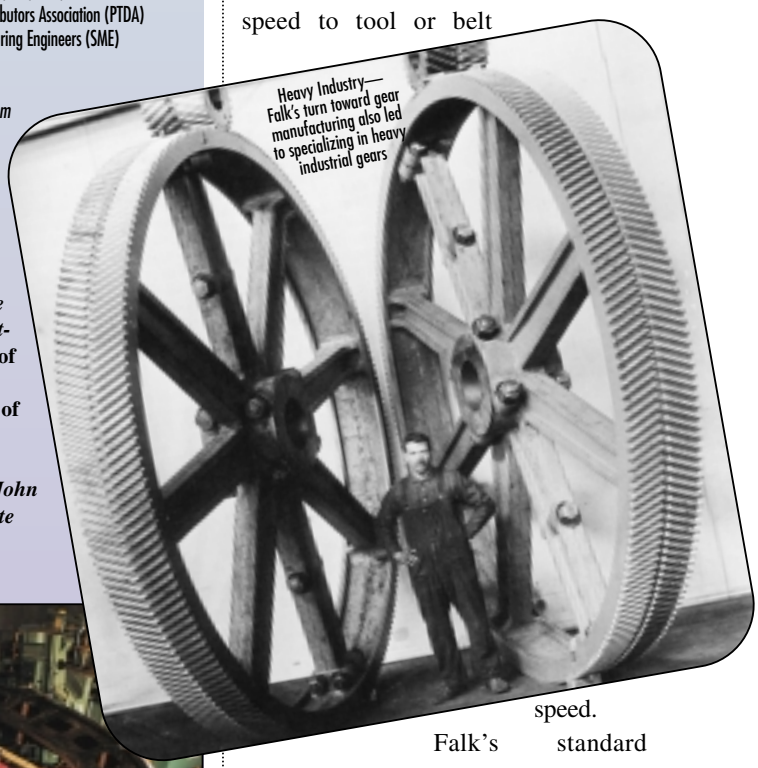
Falk's gear business was growing rapidly. The company not only made its own gears and pinions, it also supplied them to streetcar manufacturers.

Falk: A Gear Company

The gear industry in general was growing.

According to Gurda, the rise of the electric motor led to the rise of gear-driven machinery in industry.

In the 1890s, factories started to use electric power instead of steam power. But electric motors operated most efficiently at speeds too high to directly drive a machine tool or conveyor belt. Gears, however, could reduce motor speed to tool or belt speed.



Heavy Industry—Falk's turn toward gear manufacturing also led to specializing in heavy industrial gears

Falk's standard product was the spur gear, which was cut by shaping. Most Falk gears ended up in streetcars.

But, around 1909, Herman learned about a Swiss version of the hobbing machine. This version was designed to manufacture double helical, or herringbone, gears. The herringbone gear had been patented in 1901 and the hobbing machine in 1904. The Falk Co. pur-

The Falk Corp.

Established: 1892

No. of Employees:
More than 1,000 worldwide

Size of Factory:
More than 1.8 million square feet of manufacturing space worldwide

Main Industries Served:
Mining, Paper, Power and Cement

Major Products:
Gear drives, Standard shaft and fluid couplings, Service products (replacement parts, repair/rebuild services), Large open gearing, High alloy steel castings

Quality Registration:
ISO 9001-2000

Industry Affiliations:
American Foundry Society (AFS)
American Gear Manufacturers Association (AGMA)
Conveyor Equipment Manufacturers Association (CEMA)
Institute of Electrical and Electronics Engineers Inc./Portland Cement Association (IEEE/PCA)
Power Transmission Distributors Association (PTDA)
Society of Manufacturing Engineers (SME)

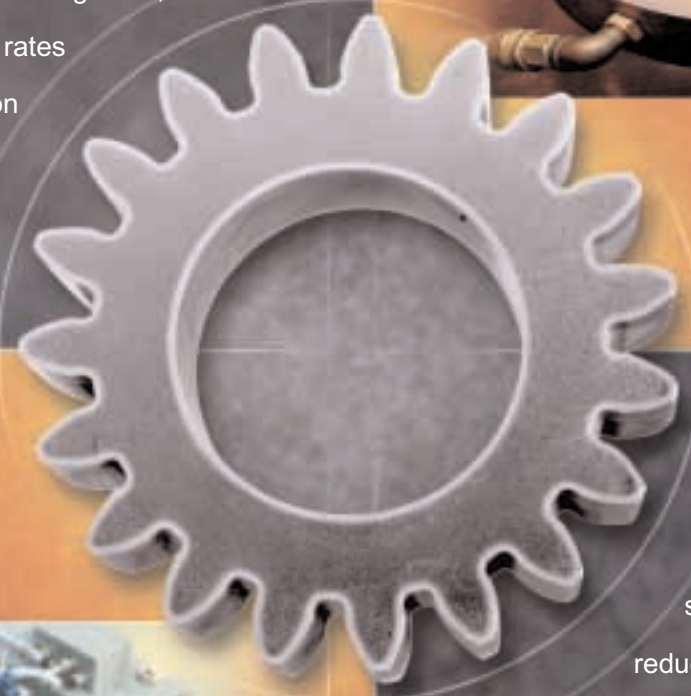
Website:
www.falkcorp.com

The Falk Corp.'s history was created from the history section of its website. The section itself was created from* The Making of "A Good Name In Industry": A History of The Falk Corp. 1892–1992*, written by Milwaukee historian John Gurda to commemorate Falk's first 100 years.

Crushing Copper—Falk employees stand inside a ring gear with a diameter of 43 feet (13.2 meters). After manufacture in Milwaukee, the gear went to a Chilean mine to crush copper ore.

Simultaneous Dual Frequency Gear Heat Treating

Inductoheat's gear hardening process uses two frequencies to concurrently heat gears inside and out, reducing stresses that cause cracking and distortion. Simultaneous Dual Frequency (SDF) technology improves quality and efficiency while cutting costs, yielding higher production rates than conventional induction heating processes.



SDF benefits include shorter heating cycles, reduced distortion and improved mircostructure. It is also easily integrated into new or existing manufacturing lines or as a flexible workcell. Contact Inductoheat to learn how SDF can improve your existing process.

INDUCTOHEAT®
An Inductotherm Group Company

32251 N. Avis Dr., Madison Heights, MI 48071
• Tel: 248/585-9393 • Fax: 248/589-1062 • E-mail: sales@inductoheat.com
www.inductoheat.com

chased the American rights to the Swiss patents in 1909. In 1911, Falk brought its herringbone gears to market.

"Herman's decision to enter the precision gearing field was undoubtedly the pivotal event in the company's history," Gurda says.

Once committed to gears, Falk started to make the type of gears it still makes today: large industrial gears.

The company's early sales were heavy-duty units that transmitted the power to crush ore, roll red-hot steel, grind raw rubber, tilt blast furnaces, generate electricity, and pump water to cities.

Falk's initial customers included Carnegie Steel, Anaconda Copper, Allis-Chalmers, Firestone, Goodyear and General Electric.

By 1914, Falk was manufacturing gears for naval and other oceangoing ships. In these ships, the steam engine was being replaced by the steam turbine. The turbine's higher speeds required reduction gears.

Falk has manufactured more than 1,200 reverse reduction drives for tugboats and towboats and more than 1,800 special reduction gears for cruise ships, aircraft carriers, tenders, ore carriers and other marine vessels.

Falk Parents: Sundstrand, UTC

Since opening in 1892, Falk had been an independent company, owned by no other company. In 1968, Falk was bought by Sundstrand Corp., an American aerospace and industrial company based in Rockford, Illinois.

In 1999, Sundstrand was bought for $4.3 billion by United Technologies Corp. Based in Hartford, Connecticut, UTC is one of the 30 industrial companies used in the Dow Jones index, with businesses in the aerospace, elevator, air conditioning and security systems industries.

The purchase improved UTC's aerospace business, expanding its range of products. Sundstrand's aerospace business was combined with UTC's aerospace unit, the Hamilton Standard division, and started operating under the name Hamilton Sundstrand.

The two aerospace units complemented each other.

But Falk and its fellow Sundstrand industrial subsidiaries—The Milton Roy Co., Sullair Corp. and Sundyne Corp.—didn't seem to fit as well with UTC operations.

"UTC did not have any other major industrial manufacturing operation at the time," says H. Peter Davis, Falk's vice president–marketing.

So, when UTC bought Sundstrand, some people wondered: What would happen to Falk? Would UTC sell it?

"We really didn't know," Davis says. Now a 36-year Falk employee, Davis was director of business development when UTC bought Sundstrand.

But he could see a reason for UTC keeping Falk: "Our profitability levels were strong."

UTC's strategy included aggressive growth in industrial manufacturing, so

Flying Over Falk—In America, Falk's main factory consists of 1.1 million square feet and is the bulk of Falk's worldwide manufacturing space, about 1.8 million square feet.

Falk and its sister subsidiaries were placed in the new Hamilton Sundstrand industrial division.

"UTC has decided that these industrial units have a good foundation that can be built upon," Davis says. "We're fully confident and comfortable that we're a part of UTC's future."

Falk Today

Now, Falk is a long way from its days of making wagon couplings.

Today, Falk's standard and custom-engineered products are used by many industries, including paper, mining, cement, power generation, steel, coal, grain, marine transportation, food processing and chemicals.

Of these industries, 60 percent of Falk sales are to the paper, mining, cement and power industries. Also, 75 percent of its products are standard products, such as gear drives, shaft and fluid couplings, and low-speed backstops. The remaining 25 percent are custom-engineered products and include special gear drives, open gears, marine drives and steel castings.

And 80 percent of Falk sales are in North and South America.

Falk is also international in its manufacturing base. Besides its Milwaukee plant, it has factories in Australia, Brazil, Canada, China and Mexico.

Falk Tomorrow

Falk's international customer base is aiding it now as businesses continue to weather the still somewhat sluggish global economy.

"Overall, we're seeing the recovery of our industry, primarily driven by the infrastructure growth in Asia," says Dave Doerr, Falk's president.

Doerr became president Oct. 1. Before the UTC purchase, he worked in Sundstrand's aerospace and industrial operations. An employee for more than 30 years, he's held positions in manufacturing, sales, and operations at Falk and with Hamilton Sundstrand.

As for Falk's future—new products, services, markets, Doerr says: "Our strategy is not unlike many manufacturers. We have to address global manufacture, global competition, and position ourselves to take advantage of it." ⚙

Tell Us What You Think . . .
Send e-mail to *wrs@geartechnology.com* to
• Rate this article
• Make a suggestion
Or call (847) 437-6604 to talk to one of our editors!

IMTS IS COMING TO CHICAGO

Registration fees: Free for international visitors!

Before August 6, 2004—$20 After August 6, 2004—$50
**After September 1, 2004, you can only register at the show.*

Show Hours: Lakeside Center: 9 a.m.–5 p.m.
South Building and North Building Hall B: 10 a.m.–6 p.m.
Sunday, September 12: All buildings: 10 a.m.–4 p.m.

To register, contact The Association for Manufacturing Technology at:
Telephone: (888) 346-8925 • Fax: (301) 694-2124 • Internet: *www.imtsnet.com*

Pavilions:
Abrasive Machining/Sawing/Finishing—North Building, Hall B
Controls & CAD/CAM—East Building, Hall D
EDM—East Building, Hall D
Emerging Technology—South Building, Ballroom S100
Fluid Power—Lakeside Center Building, Hall D
Gear Generation—North Building, Hall B
Machine Components/Cleaning/Environmental—East Building, Hall D
Metal Cutting—South Building, Hall A
Metal Forming & Fabricating/Laser—North Building, Hall B
Quality Assurance—East Building, Hall D
Tooling & Workholding Systems—East Building, Hall E

IMTS '2004 MAKEOVER

Like many businesses in this economic cycle, the IMTS marketing team is forced to look for clever ways to make a profit.

In its heyday, the show attracted 117,000 visitors. The numbers have dropped off in the last few shows, but organizers are optimistic that they can bring attendance up to the pre-recession level.

"Realistically, we'll never go back to 117,000 or 115,000 (attendees) again," says John Krisko, director of exhibitions for IMTS. "We're shooting for 100,000, which would bring us to where we were in 2000."

The declining number of industry personnel has forced the show's organizers, the Association for Manufacturing Technology, to find new ways to make their show more appealing.

GUEST LIST

Having previously worked in the machine tool industry, Krisko understands the importance of quality leads.

To help IMTS attendees get those two substantial sales that can justify the show's expense and time, the AMT has implemented the "Most Wanted" program.

Early this summer, exhibitors will be able to submit a list of 10 ideal people they would like to appear at their booth. AMT will send out free MVP passes to everyone on the wish list and tell them which company has requested their presence. They'll then go back to the

exhibitor and report on the status of the MVP invite.

"It's our way of going more personal and getting away from using the alumni list for the lead count," he explains.

REALITY TV

Even if you're not a VIP invite, you'll still have the chance to take a break from the show by visiting TLC's "Junkyard Wars" display.

For the first time ever, IMTS will feature an on-site, interactive display of the popular cable show. While the network has not promised to make reality TV stars out of IMTS groupies, there is a chance that portions of the taped versions will appear on TLC.

The IMTS 2004 manufacturing conference will focus on lean manufacturing, machining and tooling, manufacturing strategies and new technologies through speeches and networking events.

This event will be held concurrently with IMTS 2004. Each conference series contains several focused technical sessions.

Speeches are broken down into 40-minute presentations. In addition, half-day workshops will be held to discuss technology advancements, quality standards and strategies for improving manufacturing operations.

Exhibitors are eligible for a $100 discount on the conference registration fees. For more detailed pricing information, contact SME Customer Service by telephone at (800) 772-4404 or on the Internet at *www.sme.org/imts*.

Participants will be divided into three four-person teams to build a gravity-powered vehicle from an assortment of spare parts. After 10 minutes, building time is up and attendees can race their creations against each other along a crash course that's complete with a 16-foot hill, a smoking tunnel, wall of fire, speed bumps and death drops.

Flanked by plasma TVs facing all directions that broadcast the competition to the rest of the show, the "Junkyard Wars" display is located in Hall D in the Lakeside Building.

LEARNING CENTER

More mainstream than the road races, but also new for IMTS 2004 is the Emerging Technology Center, a compa-

ny showcase of developing manufacturing technologies that's located in the Grand Ballroom of the South Building.

This idea was a result of the survey from IMTS 2002, in which attendees reported that their top reason for traveling to the show was to see new technologies.

"In that respect, the show management has not done as good a job of educating attendees as the companies," says Krisko. "With the new center, we'd like to see IMTS move back toward where it was in 1927—an educational experience, rather than sales-focused."

Hopefully, the ETC will achieve that by continually presenting a high-tech documentary that runs for 10–12 minutes. Subjects featured include the newest conceptual technologies, status of industry research and an overview of opportunities in manufacturing. Featured topics include ultra-small-scale manufacturing, new automation techniques, cryogenics and dry machining, smart machines and alternative processes.

NEW PAVILION

The Fluid Power Pavilion will be introduced this year, jointly sponsored by IMTS and the National Fluid Power Association.

Focusing on motion control solutions for machines, these exhibits will feature hydraulic and pneumatic components, systems and controls. It will be located in the Lakeside Center Building, Hall D.

HOLDING RATES STEADY

A variety of hotels are offering rates that are the same as or less than what they were in '02. Complete travel information, including airlines and hotels, is available at *www.IMTS.com*.

Organizers have also renegotiated labor rates to remain consistent with those in 2002.

Krisko summarizes, "IMTS is a major event and we want to keep it that way. Everyone knows that there aren't as many of us to call on as in the past, so we've made some changes and look forward to a successful IMTS 2004." ⚙

Hooking Them Young

A tradition at IMTS since 1998, the Student Summit aims to introduce grade school, high school and college students to career opportunities in manufacturing.

Student Summit mentors and IMTS student-friendly exhibitors can provide information on recruiting new talent to the industry.

AMT recommends that exhibitors with student-friendly booths designate a human resources manager or company president to interface with students.

Educator and Student Summit registration is free and good through the duration of IMTS. Total attendance from the 2002 Student Summit reached 4,331.

For more company participation information, complete the Student Summit Mentorship application online at *www.imtsnet.org* or contact Tracy Hirsch by telephone at (703) 827-5222 or by e-mail at *thirsch@amtonline.com*.

However you need your gears machined KLINGELNBERG HAS A WAY

Gear Cutting

CNC bevel gear cutting, wet or dry, is state-of-the-art machining. Modularly designed machines assure precision operating and high speeds promote high volume throughput.

Testing and Lapping

Using a proven horizontal spindle concept with cross-sledge design, these machines have a small footprint with optimal process capability.

Measuring

A new dimension in gear measuring is presented: highly compact in size, economical, and with the latest technology for automatically measuring workpieces up to 260 mm in external diameter.

Tooling

Klingelnberg/Oerlikon tooling is available for our machinery and for other makes and models of contemporary gear machining mechanisms.

KLINGELNBERG

KLINGELNBERG OERLIKON

Contact :
Liebherr Gear Technology · 1465 Woodland Drive · Saline, MI 48176-1259
Phone 734.429.7225 · Fax 734.429.2294 · info@lgt.liebherr.com

SIGMA POOL

The Partnership of KLINGELNBERG and LIEBHERR
GEAR CUTTING · GEAR GRINDING · MEASURING · GEAR HOBBING · SHARPENING · GRINDING

SNEAK PREVIEW

There's a bustle of activity as exhibitors prepare for America's most significant manufacturing trade show. The red carpets are ready, the lights are being tested, and the crowds are gathering with anticipation. Amid the excitement, **Gear Technology** *has managed to sneak under the usher's ropes to provide you with this advance look at some of the gear-related products and technologies that will be featured at IMTS 2004.*

New LMT-Fette Tool for Chamfering/ Deburring in the Hob Machine

LMT-Fette will introduce a new chamfering/deburring tool for use in hob machines, a new tool steel and two new coatings.

The new tool is called Chamfer Cut. It allows gear manufacturers to produce consistent chamfering and deburring of parallel-axis gears, both spur and helical.

Darryl Witte, product manager–gear tools, says Chamfer Cut will allow gear manufacturers to reduce the many hours that manual deburring takes and reduce high costs associated with specialized chamfer machines and their tools.

The tool steel is PM35 tool steel. The functional coatings haven't been named yet. The steel can be used in wet and dry cutting applications with an operating speed range of up to 350 meters per minute. All three products are designed to maximize tool life in production gear cutting.

"We are pushing the envelope as to how fast and productive PM HSS materials can run," Witte says. "In some cases, our new PM35 HSS material is running quite close to cutting conditions once reserved for carbide."

Also, LMT-Fette will feature the increased capabilities of its HDR hobs. The hobs have been optimized for roughing and finishing operations to save time and cost. The hobs' range is now as fine as 6 DP.

The company will also feature shank-type tools with quick-change HSK hydraulic chucks for ease of set-up and increased accuracy on later-model hobbing machines. The idea behind the tools is to allow customers with multiple machines having different spindle clamping mechanisms to use common shank-type tooling.

"Previously," Witte says, "these tools would need to be bore-type hobs and have a greater chance to introduce runout to the tool or [would need] specialized tools for each machine."

Since IMTS '02, LMT-Fette has implemented a new business model to increase its attention to detail and its turnaround for providing tools, from concept to final delivery.

Witte says this model should provide many benefits to new and existing customers.

LMT-Fette (Booth E-2873)
18013 Cleveland Parkway, Suite 180
Cleveland, Ohio 44135 U.S.A.
Phone: (216) 377-6130 • Fax: (216) 377-0787
E-mail: *lmtfette@lmtfette.com* **• Internet:** *www.lmtfette.com*

Chromium: The Base of Balzers' New Tool Coating

Balzers Inc. will unveil a tool coating that can be used on hobs and features increased wear resistance. The coating, Balinit® Alcrona, is the first of the new G6 coating generation developed by Balzers.

Titanium has been the base of benchmark coatings such as TiAlN, TiCN or AlTiN. With Alcrona, Balzers has developed a coating based on chromium. The coating's formula is in its name; Alcrona is AlCrN, an aluminium chromium nitride.

Dennis T. Quinto, Balzers' technical director, calls Alcrona the "cornerstone" for its new generation of PVD coatings and says it'll open "a new productivity dimension in machining."

Quinto emphasizes Alcrona's wear resistance, which he calls "unrivalled" and which result from two main features, the coating's hot hardness and oxidation resistance.

As a Balinit coating, Alcrona is designed for dry and wet machining of unalloyed steels as well as steels of high strength and high hardness (up to 54 HRC).

Balzers is a leading global supplier of hard and lubricant PVD coatings for improving the performance and service lives of precision parts, metalworking tools and plastics processing tools.

Balzers offers coating systems, turnkey production lines and contract coating services through its network of 57 coating centers in Europe, North and South America, and Asia.

Balzers Inc. (Booth E-2748)
555 Commerce Drive
Amherst, New York 14228 U.S.A.
Phone: (716) 564-8557 • Fax: (716) 564-0206
E-mail: *info.us@balzers.com* **• Internet:** *www.bus.balzers.com*

Euro-Tech: New Coatings on Chucks, Arbors, Master Gears

Euro-Tech Corp. will feature Wolfram carbide coatings on its Mytec chucks and arbors and feature a new generation of chamfered, coated master gears.

The carbide coating provides chucks and arbors with a sleeve hardness of 72 HRC to decrease wear and can be applied to the expansion

IMTS COVERAGE

area only to decrease costs. According to Jerry Kowalsky, Euro-Tech's president, another advantage of the coating is extreme holding power with a minimum amount of expansion.

Made by Frenco GmbH, the Chaco master gears allow gear manufacturers to perform single- and double-flank gear rolling inspection as an integrated process in production.

Kowalsky says this integration saves time and money.

The coated master gears offer protection against wear and corrosion. They're also harder and provide manufacturing tolerances meeting the exacting demands placed on modern master gears. Tolerances were selected with DIN standards in mind.

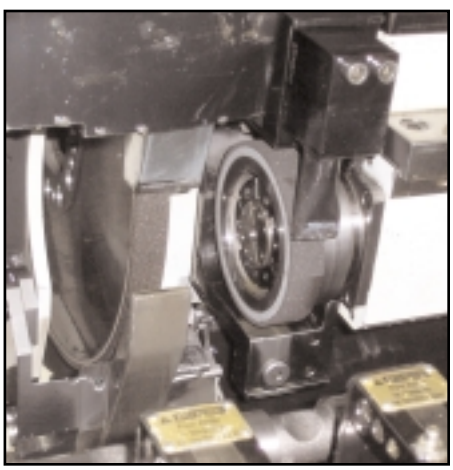
Euro-Tech represents a number of European-made gages and tooling products, such as arbors, chucks, drills, taps, measurement systems and accessories.

Mytec GmbH is a leading manufacturer of fully brazed, rupture-proof construction hydraulic expansion clamping tooling.

Frenco provides shop-floor measuring equipment in the gear and spline fields.

Euro-Tech Corp. (Booth E-2672)
N48 W14170 Hampton Ave.
Menomonee Falls, Wisconsin 53051 U.S.A.
Phone: (262) 781-6777 • Fax: (262) 781-2822
E-mail: *info@eurotechcorp.com* **• Internet:** *www.eurotechcorp.com*

Saint-Gobain Rolls Out New Abrasive Wheels



Saint-Gobain Abrasives will unveil five new products: two lines of bonded abrasive wheels, two lines of superabrasive wheels, and a line of coated abrasive belts.

The two lines of bonded abrasives consist of the XGP line and Altos® creepfeed wheels.

The XGP line is designed to lower cost per part. Its products hold their forms better than other conventional fluting products. Less required dressing permits higher metal removal rates, longer wheel lives, tighter part tolerances, and lower grinding power, according to Barry Cole, Saint-Gobain Abrasives' manager–industrial marketing & marketing communications.

The Altos wheels use an extruded ceramic grain with high length-to-diameter ratio. Cole says these wheels have a more consistent open structure for more effective coolant flow and better chip clearance and

can reduce cycle times up to 50 percent and increase the number of parts produced per wheel by three to four times.

The superabrasive lines are T2 wheels, which are vitrified CBNs, and Univel DC wheels.

The T2 line is designed for high-volume, precision ID and OD grinding for a range of ferrous parts, including cast iron, steel, powder metals and high-nickel alloys. Applications range from automotive camshafts to fuel injectors and aerospace jet blades.

The new Univel DC wheels are designed to maximize productivity of CNC grinders and thereby lower total grinding and finishing costs. Cole says the wheels' bond has a cool cutting capacity, which allows the wheels to maintain their grain longer, increasing the number of parts per dress and total parts per wheel.

According to Cole, operators can increase infeed rates up to two times to reduce cycle time without loading the wheel or damaging the cutting tool.

The fifth new product is the Norax line® of coated abrasive belts.

These fine-grit products have abrasives and bonds that can be formed in 3-D structures. According to Cole, these structures offer multiple patterns that can increase life, increase cut rate, improve surface finish and improve stock removal efficiency.

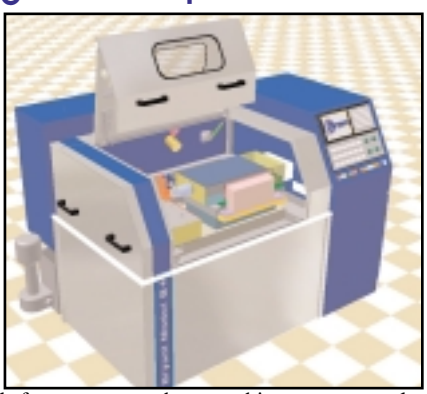
"Norax products are uniquely suited for finishing high value-added robotic grinding applications, many of which are used to replace off-hand manual finishing applications," he says.

Saint-Gobain Abrasives will feature its sensors and measurement abilities and how they can help customers.

Since IMTS '02, Saint-Gobain Abrasives has increased its ability to measure and analyze the grinding process to support customers.

Saint-Gobain Abrasives Inc. (Booth B-7033)
1 New Bond St., Box 15008
Worcester, Massachusetts 01615, U.S.A.
Phone: (508) 795-5000 • Fax: (508) 795-4130
E-mail: ***john.r.blake@saint-gobain.com***
Internet: ***www.sgabrasives.com***

Bryant Grinder: Bringing in the New, Showing Off the Improved



Bryant Grinder, a division of Vermont Machine Tool, will unveil two new grinding machines, the UL2 and the B+. Both models include Fanuc linear motors and controls. Also, the B+ has extended travel, three inches along both the x- and z-axes.

The grinding machine manufacturer will feature two other machines, two newly designed Bryant grinders, and Bryant high speed motorized spindles and dressing systems.

In the past two years, Bryant has improved its existing technologies by including sensors and linear drive systems with its existing hydrostatic way system. Moreover, all new Bryant equipment with GE Fanuc controls will incorporate Ethernet capabilities for direct factory support for software and electrical diagnostics for troubleshooting and overall

The Gearless Hydrostroke:

Bourn & Koch's State-of-the-art Upgrade of the Classic Fellows Machine Will Be on Display at IMTS 2004.

by Dr. Bob Winfough, Engineering Manager, Bourn & Koch

The Gearless Gear Shaper™, also known as the new generation HS650, is an electro-mechanical machine that takes advantage of the heart of the Hydrostroke™, integrated with state-of-the-art CNC control, digital motors and drives and application of control system theory, structural dynamics, improved mechanical design and strategic use of materials. Also, a value engineering approach reduced the number of parts in the machine by more than 50%.

The new generation HS650 vertical shaper integrates all of this technology to provide a modern, robust solution for shaping gears. See Table 1 for a physical description of the machine.

Stroke Axis: The Hydrostroke Edge

Key Hydrostroke technology has been integrated into this new generation shaper. The Hydrostroke advantage—the quick return action that made the older generations of machines so productive—is still at the heart of the new machine. However, the new generation HS650 integrates positioning, stroke and return ratio settings into a single axis, which allows for simplified end-user setup and increased programming flexibility.

A linkage attached to a rotating shaft drove previous generations of the Hydrostroke spindle. This arrangement made it difficult to estimate true cutting performance. The new arrangement allows the Hydrostroke to be led by a linear actuator. This actuator is a high-force linear motor provided as a complete package from the CNC provider.

Another benefit of the Hydrostroke is concentric force loading on the spindle, providing less wear and damage to spindle support bushings. The Hydrostroke also allows for direct measurement of the cutting pressure by reading the load sensor, which itself is used to adaptively control the supply pressure for energy efficiency.

The new design is compatible with previous tooling, including the 50-8, FS630-200 and similar models.

CNC Guide

The new Gearless Gear Shaper provides a gearless CNC guide as well. To date, CNC guide technology hasn't allowed gear shapers to be used for high production. The technology can't produce helical gears at a rate as high as a dedicated mechanical guide system. The CNC guide of the Gearless Gear Shaper has been designed to match the high stroking speed of the Hydrostroke with a high-performance rotary action, which helps maximize productivity.

The Gearless Gear Shaper can also meet high production demands by using dedicated mechanical guides that can be integrated to get maximum utilization for full production requirements. Having the capability to utilize both the CNC guide and rigid guides allows the high-production manufacturer to do proof-of-concept work on new gears, satisfy early production requirements and specify the final helix requirements in the design cycle. This allows a strategic overlap between the end of previous production and the ramp-up of new product. This also allows smaller volume production shops to use the CNC guide exclusively.

A high-precision, high-stiffness bearing—allowing the high-torque digital integral motor to rotate the spindle to perform high-speed helical motions—supports the Hydrostroke cutter spindle. The arrangement takes advantage of common components on previous generations of Fellows machines, making spare parts more readily available and minimizing the customers' inventory and spares costs.

Oriented Stiffness, Simplified Back-Off™ and CNC Roll-Over™

The Gearless Gear Shaper is also a cam-less gear shaper. On previous generations of machines, back-off cams, bearings and spring tension required substantial maintenance cost and caused setup difficulties. The HS650 was designed to simplify the operation, maintenance, assembly and manufacture while providing increased capability. As a result, cams, rotary bearings and spring tension required in most gear shapers have been eliminated. The new arrangement provides stiffness in the proper orientation to allow the required rotations without the use of bearings or expensive, hard-to-maintain cams. Additionally, the orthogonal directions provide increased stiffness in the direction required to

Table 1—The Gearless Gear Shaper, Model HS650-200 from Bourn & Koch

Capacities	Metric (mm)	Inch (in.)
Nominal Pitch Diameter		
External	650	25.6
Internal	635	25
Rated Pitch		
Spur	12.7 MOD	2 DP
Helical	12.7 MOD	2 DP
Max. Gear Face Width	200	8.0
Max. Helix Angle	40 Deg.	
Min. Center Distance	-10	-0.39
Max. Center Distance	700	27.6
Max. Part Swing	1,000	39.4
Max. Strokes per Minute	500 spm	
Dimensions		
Length	5,334	210
Width	2,470	98
Height	3,125	123
Weight (kg/lb)	13,600	30,000

oppose cutting forces.

When switching from an internal gear to an external one, there is no need to reverse or "roll over" the cam. This is now handled entirely by the CNC program. The user has only to program a negative motion by adding a minus sign.

Constructed with an oriented stiffness design, the axis is attached to a high-force linear actuator. The design allows for a large force amplifier, enabling extremely high force to oppose the potentially large cutting load.

C-Axis Table Construction

The machine's table was also redesigned to accommodate a high torque digital motor assembly integrated with a high precision rotary encoder, providing up to 250 times the rotational accuracy when compared with traditional worm and worm wheel setups. Combined with the CNC guide axis, which is more than 100 times more precise than the corresponding worm, this will provide for more precise location of the cutting edge. Other advantages of the new design include no backlash, no worms and no worm wheels, while maintaining the previous features of through-the-spindle chip evacuation and an internal work clamp cylinder.

Vertical Positioning Axis

The HS650 has been designed with a gantry twin ball screw arrangement to allow the user to reposition the cutter spindle via the CNC part program. The motion range is 300 mm long and allows the user to move the cutter spindle slide housing up and down to accommodate different gear locations along a shaft or perhaps multiple gears on the same shaft when integrated with a tool change.

In-Feed Axis

The in-feed axis has been constructed to allow quick access to parts through a standard ball screw transmission with a direct coupled servo motor. The axis has been constructed in a manner to allow the addition of an extension riser and also for manual introduction of cutter rub movement.

Overall Machine Improvements

General Machine

- 50% reduction in number of machine parts
- 2-pick movable package
- Complete machine enclosure, with sloped chip evacuation surfaces
- Modular, multiple-platform package (shaper, hobber, grinder)
- Front or rear chip conveyor discharge
- No-drip base design for containing coolant and all lubricants

Control System

- State-of-the-art CNC
- GUI interface that allows the user to input gear geometry and then see the construction of the physical workpiece in real time on the screen

For more information:

Bourn & Koch Inc. (Booth B-6912)
2500 Kishwaukee St.
Rockford, IL 61104
Phone: (815) 965-4013 • Fax: (815) 965-0019
E-mail: *bournkoch@worldnet.att.net*
Internet: *www.bourn-koch.com*

capability.

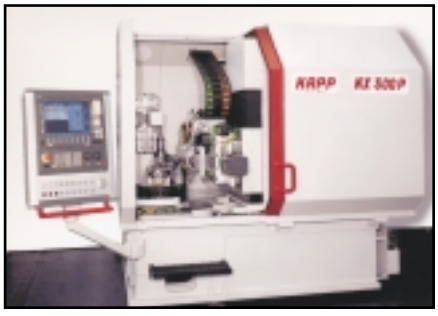
"We've made technological changes with linear motion and control," says Craig B. Barrett, Bryant's president and CEO, "and sensors embedded into the machine which can predict machine failure or machine problems prior to failure.

"We have also reduced overall price of all our Bryant product lines."

Bryant Grinder provides grinding machines designed for high productivity and precision and offers remanufactured machine tools.

Bryant Grinder (Booth B-6836)
65 Pearl Street, Springfield, Vermont 05156 U.S.A.
Phone: (802) 885-5161 • Fax: (802) 885-9444
E-mail: *sales@bryantgrinder.com* • Internet: *www.bryantgrinder.com*

A New Alliance: Kapp-Koepfer



The Kapp Group will join Koepfer America LLC in presenting for the first time a Koepfer-Kapp machine for hard finishing external spur and helical gears up to 120 mm in diameter.

The jointly developed machine fills the gap between skiving on gear hobbing machines and generating grinding on specially designed gear grinding machines, says Tom Lang, Kapp Technologies' vice president and general manager.

Based on Koepfer's model 200 gear hobber, the machine has a high-speed grinding spindle and can perform continuous generating grinding and single index form grinding. The machine uses Kapp non-dressable tools, with Koepfer's automation and magazine systems completing the new system.

Also, responding to customer requests, Kapp developed a new gear grinding machine able to perform continuous generating grinding and single index form grinding.

Kapp Technologies will introduce this new machine, the KX300P, at McCormick Place.

"This dual capability makes this machine perfect for job shops that run low volumes or prototypes using the form grinding process," Lang says, "or serial production facilities that produce hundreds or even thousands of parts."

The KX300P can be automated and fitted with integrated inspection.

Kapp will feature plated grinding tools and announce their increased availability, too. Kapp has increased capacity at its manufacturing facility, allowing it to expand its delivery of CBN products from just Kapp equipment owners to the entire gear industry.

Since IMTS '02, Kapp has added grinding with globoidal CBN grinding worms to its offerings and extended its Coroning® process by coroning without crossed axis angle for finishing shoulder gears and similar parts with limited geometric characteristics.

It's also continued to upgrade its machines to Siemens 840D control systems so all Niles ZP and ZE series machines now use this control, complete with Siemens digital drive technology. All new Kapp KX and CX series machines also use the 840D, direct drive tool and work spindles, and Siemens digital axis drives.

IMTS COVERAGE

Kapp Technologies manufactures gear grinding machines, including profile and worm grinding machines and honing machines. It also manufactures grinding tools, such as grinding wheels and worms and honing tools.

Kapp Technologies (Booth B-6931)
2870 Wilderness Place
Boulder, Colorado 80301 U.S.A.
Phone: 303-447-1130
Fax: 303-447-1131
E-mail: ***sales@kapp-usa.com***
Internet: ***www.kapp-usa.com***

New Software, New Models: M&M Expands Capabilities

M&M Precision Systems Corp. will display its new eDRO data interface system with one of its Dimension Over Pins gages.

eDRO collects data in real time for today's networked process control requirements using Ethernet, RS-232 or serial connections or a removable memory media.

"The system offers the ability to configure part-specific tolerances, machine-specific data trends, calibration routines and display pass/fail results to the operator," says Douglas Beerck, M&M's general manager.

Also, Sigma and MicroTop CNC gear analyzers will display new software features, such as new non-gear inspection capabilities for people who want a more universal solution to four-axis measuring requirements.

M&M will also feature CNC gear analyzers and tabletop roll testers, as well as information on its fully automatic and semi-automatic gear roll testers, DOP gages, spline gages and master gears.

Since IMTS '02, M&M has improved its existing products by adding two new models to its Sigma series of CNC gear inspection systems. The Sigma 10 and Sigma 15 systems measure gears with diameters up to 1 meter and 1.5 meters, respectively.

Responding to customers, M&M obtained A2LA certification for its gear certification laboratory.

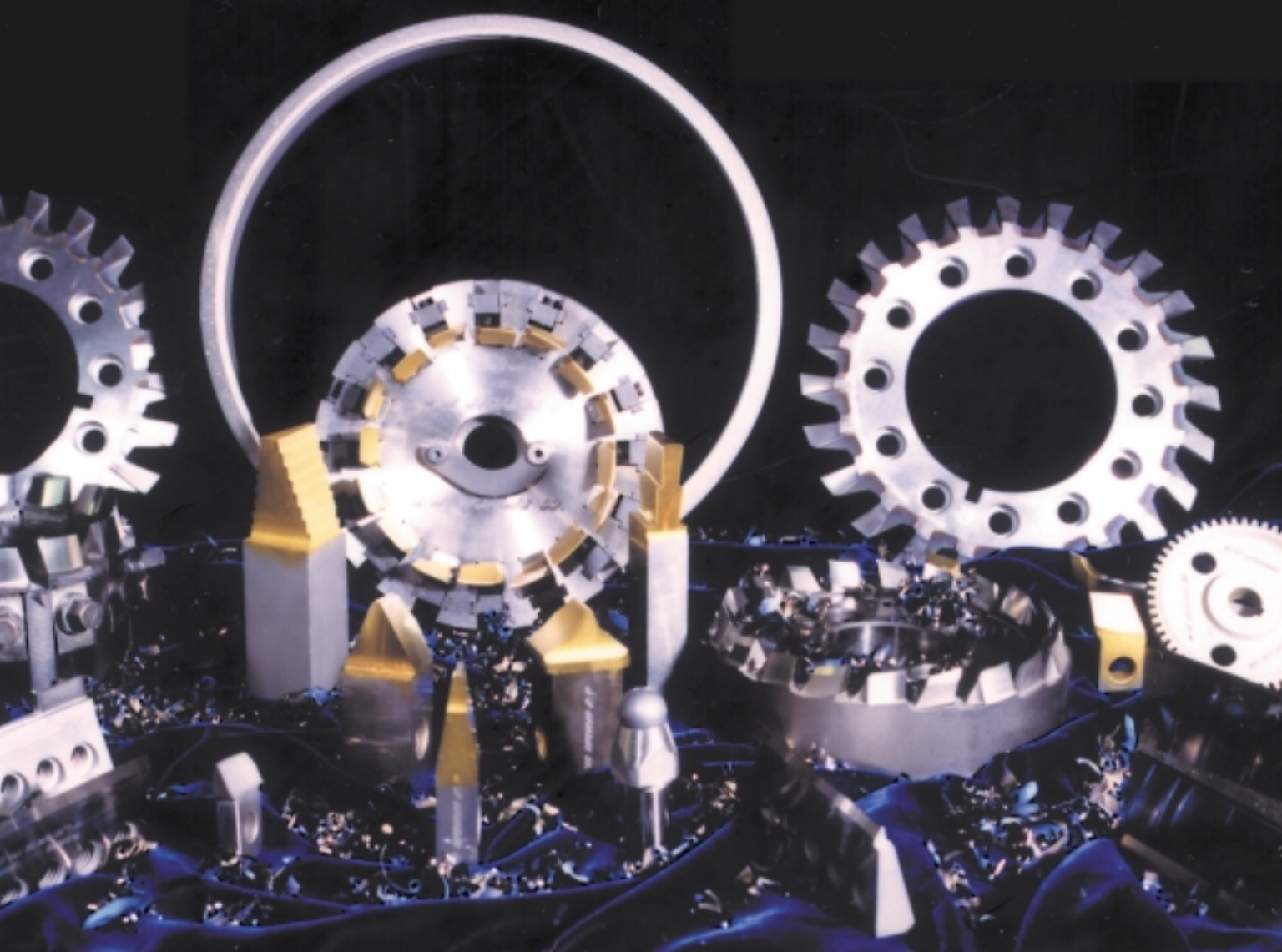
Also since IMTS '02, M&M has added a line of automatic and semi-automatic gear roll testers. And M&M's new eDRO system has its own microprocessor, so it can be obtained as a standalone unit for interfacing to a variety of gages and micrometers.

M&M manufactures specialized inspection and gear manufacturing process control systems for all types of gears.

M&M Precision Systems Corp. (Booth B-7107)
300 Progress Road
Dayton, Ohio 45449 U.S.A.
Phone: (937) 859-8273
Fax: (937) 859-4452
E-mail: ***HartzellB@MMPrecision.com***
Internet: ***www.mmprecision.com***

Quality Spiral Bevel Tools

A/W Systems Co. is your quality alternative manufacturing source of spiral gear roughing and finishing cutters and bodies.
We can also manufacture new spiral cutter bodies in diameters of 5" through 12" at present.
A/W can also supply roughing and finishing cutters for most 5"–12" diameter bodies.
Whether it's service or manufacturing, consider us as an alternative source for cutters and bodies.
You'll be in for a pleasant surprise.



Sun Cutter Co. LLC

Royal Oak, MI 48067
Tel: (248) 544-3852 • Fax: (248) 544-3922
Come See Us At Booth #7218–IMTS 2004.

A/W Systems Co.

First Time in America: Reishauer's New Gear Grinder

Exhibited for the first time in the United States will be a twin spindle gear grinding machine, new from Reishauer Corp.

Model RZ 150's work spindles are direct driven with digital servo motors. The machine itself takes up 54 square feet of floor space.

Dennis Richmond, Reishauer's vice president, says this footprint makes the RZ 150 "one of the most compact gear grinding machines on the market today."

Reishauer will also exhibit a variety of diamond and CBN tools used in manufacturing gears.

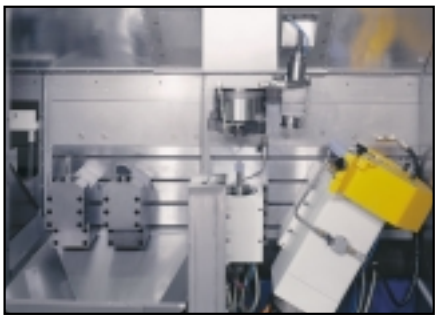
Since IMTS '02, Reishauer has made technical improvements to its products, but it also increased productivity and quality by developing other ways of hard finishing gears. According to Richmond, these ways essentially change the thought process used to grind gears.

"The use of such 'tools' as multi-start grinding wheels, our cool cutting meth-od and LNS (low noise shifting) have allowed us to make dramatic gains," Richmond says.

Reishauer sells gear and thread grinding machines and diamond tools. It also provides new and used machine tools.

Reishauer Corp. (Booth B-7005)
1525 Holmes Road, Elgin, Illinois 60123 U.S.A.
Phone: (847) 888-3828
Fax: (847) 888-0343
E-mail: ***reishauer@reishauer-us.com***
Internet: ***www.reishauer.com***

Combining Turning and Grinding: United Grinding's New Machine



Among 11 displayed grinding machines, United Grinding Technologies Inc. will have a new machine of interest to gear industry professionals, the Studer Schaudt Stratos M, which combines grinding and hard turning in one platform.

Dave Barber, United Grinding's marketing manager, says combining processes into one machine is a due to customers' needing to produce parts in a lean environment where one machine completes multiple tasks.

"'Done in one' is the catch phrase of the past two years," Barber says, "and the products of United Grinding address this need."

The Stratos M features a vertically mounted spindle that also acts as a loader. The first operation is "hard turning," in which the machine can be configured with up to three turning tools on separate posts or up to 8 turning tools in an indexable turret. The turret can also be specified with live tooling, allowing for light milling operations.

The second operation is grinding, both ID and OD. First, a part's ID features are ground, followed by OD features. Automatic dressing is mounted to the right of the spindle, for easy access.

Also, United Grinding will display the first Studer Autoloader, which can be integrated with most of Studer's line of cylindrical grinders.

Since exhibiting at IMTS '02, United Grinding has improved overall productivity by adding linear motor technology to the table of surface and profile grinders, developing integrated loaders, and improving the software that drives the controls.

"Basically, customers are not in a great need for increased capacity," Barber says. "Instead they need improvements to productivity to compete in the world market."

United Grinding produces grinding machines, specializing in precision Swiss and German machine tools that meet grinding needs, from tool and cutter, surface, profile, and creepfeed grinding to all types of cylindrical and non-cylindrical grinding.

United Grinding Technologies Inc. (Booth B-6700)
510 Earl Blvd.
Miamisburg, Ohio 45342 U.S.A.
Phone: (937) 859-1975
Fax: (937) 859-1115
E-mail: ***ugt@grinding.com***
Internet: ***www.grinding.com***

Credit Where Credit is Due

The article titled "A Model of the Pumping Action Between the Teeth of High Speed Spur and Helical Gears," which ran in *Gear Technology's* May/June 2004 issue, was previously published in VDI-Berichte NR.1665, 2002.

The article called "Evaluation of Bending Strength of Carburized Gears," also in *Gear Technology's* May/June 2004 issue, was previously published at the JSME International Conference on Motion and Power Transmissions held November 15–17, 2001, in Fukuoka, Japan.

Tell Us What You Think . . .
Send e-mail to ***wrs@geartechnology.com*** **to**
• Rate this section
• Make a suggestion
Or call (847) 437-6604 to talk to one of our editors!

KAPP
TECHNOLOGIES

The best will be there.

Come see the affordable machine that does it all:
generating grinding, form grinding, dressable tools,
CBN tools, and integrated inspection.

IMTS2004 Booth B-6931

2870 Wilderness Place
Boulder, Colorado 80301

www.kapp-usa.com

Ph: 303-447-1130
Fx: 303-447-1131

A/W Systems

Booth Number: B7218

Description:

A/W Systems manufactures a complete line of tooling for both straight and spiral bevel gearing. Most notable is our line of Face-Hob Cutter Bodies, which are available in all of the most common U.S. blade and size combinations (e.g. 11/64, 13/76, 17/88, 13/105, 19/105). Our In-House blade grinding capacity allows us to provide fully sharpened and coated stick blades, in M2 HSS, Rex 76, Ultra-fine grain Carbide, or any other customer desired substrate. Of course, a variety of coatings are also available.

Additionally, A/W Systems has entered into a partnership with Klingelnberg-Oerlikon Tech Center to provide state-of-the-art hypoid gear tooling technology and services to the U.S. gear manufacturing market.

Our booth will display a wide variety of gear tooling, as well as provide technical materials.

Contact:
A/W Systems
612 E. Harrison
Royal Oak, MI 48067
Phone: (248) 544-3852
Fax: (248) 544-3922

Gleason Cutting Tools CORPORATION

BOOTH #B-6902

More lean, less leadtime. Gleason Cutting Tools Corporation is leading the industry in Lean Manufacturing methods and applying advanced equipment at its ultra-modern facility in Loves Park, IL to speed deliveries and improve efficiency. Today, with so much riding on shortening leadtimes and improving quality, Gleason Cutting Tools is your single best source for:

- Hobs • Shaper Cutters • Shaving Cutters • Bevel Stick Blades
- Plated CBN Wheels and Plated Diamond Rolls • Form-Relieved Milling Cutters

A host of contract services are available as well, including tool resharpening, advanced coatings, heat treat, metallurgical lab analysis, workholding repairs, pickup/delivery and technical gear schools.

4 week delivery on shaper cutters (2 weeks for PDQ shapers); 5 weeks for hobs (3 weeks for PDQ hobs)!

For more information, visit **www.gleason.com**

Gleason Corporation

BOOTH #B-6902

Keeping the World in Motion.™ Today Gleason stands virtually alone in its ability to deliver the complete array of technologically superior gear-producing solutions. You can see many of the latest breakthroughs up close and in action at IMTS '04, including:

- PHOENIX® II 275G Bevel Gear Grinding Machine, working in concert with Gleason-Mahr's new GMX 400 Gear Inspection Machine and GEMS (Gleason Expert Manufacturing System) software to 'close the loop' on bevel gear quality.
- P 600 G Profile Grinding Machine, using new patent-pending profile grinding software to greatly reduce non-productive time and improve quality.
- P 90 Horizontal Hobbing Machine, featuring improved direct-drive spindle performance.
- The 245TWG High Speed Threaded Wheel Grinder, making hard finishing in high volumes economical.

For more information, visit **www.gleason.com**

Star-SU

Booth Number: B6912

STAR-SU OFFERS A COMPREHENSIVE LINE OF GEAR MANUFACTURING EQUIPMENT:

Machine tools
Cylindrical gear hobbing
Bevel gear cutting
Shaping
Profile grinding
Continuous generating grinding
Shaving cutter grinding
Hob grinding
Universal tool grinding
Carbide tool grinding
Chamfering and deburring

Cutting tools and services
HSS and carbide hobs
Shaper cutters
Milling cutters
Rack and saw cutters
Shaving cutters
CBN profile grinding wheels
Master gears
Chamfering and deburring tools
Regrinding of gear cutting tools
Coating of gear cutting tools
Replating of grinding wheels

Pickup and delivery services
Commodity Management Services

Round tools
Single and double flute gundrills
Solid carbide gundrills
Two-fluted milled style deep hole drills
Solid carbide drills and reamers
Pressure coolant drills and reamers
"PCD" drills and reamers
Integrated holder "PCD" tooling

Visit our website to download our complete program of products and find the match for your particular need.

www.star-su.com
sales@star-su.com
Phone: 847-649-1450
Fax: 847-649-0112

www.suamerica.com
www.starcutter.com
www.bourn-koch.com

See us at IMTS 2004, in Booth 6912, North Hall

LMT-FETTE

Booth Number: E-2873

Company Profile

LMT-FETTE blends precision German engineering with application expertise resulting in hobs that maximize quality and minimize cost per part produced. LMT-FETTE's new gearing products include:

- **Chamfer Cut:** Chamfer and deburr on a hobbing machine in one setup–no secondary operations–reducing manufacturing time, capital expenditures and tooling costs.
- **Fine Pitch Micro Hob:** Hobs down to 254 DP.
- **HDR (Broach Tooth) Hobs:** Chip breakers introduced with alternating gashes–increase tool life and feed rates, while minimizing hammering effect.
- **Expansion Chucks:** Allow shank-style tools to easily adapt to machines with tool changeable arbors.
- **Grades:** Brand new materials and coatings.

All LMT-FETTE hobs are manufactured to AGMA and DIN standards. Our broad product line of hobs includes solid, HDR, finishing, multi-gash, rotary, solid carbide, skiving, and indexable carbide hobs for roughing.

Contact

LMT-FETTE, INC.
18013 Cleveland Parkway
Suite 180
Cleveland, Ohio 44135
Phone: 800-225-0852 or 216-377-6130
Fax: 216-377-0787
E-mail: *lmtfette@lmtfette.com*
Website: *www.lmtfette.com*

Marposs Corp.

Booth Number: D4514

Need to Check Gears?

Looking for an easy, cost-effective way to check gears? The Marposs M62 bench gauge system with optional noise detection is accurate, easy to use and quickly re-toolable using ordinary hand tools. You'll save time and the cost of dedicated gauges. With the M62 you can measure:

- Radial composite deviation
- Radial runout
- Tooth to tooth radial composite deviation
- Tangential composite deviation
- Nicks
- Optional measurements include center distance, bore diameter and perpendicularity of bore to gear face.

All functional checks can be displayed on the rugged Marposs E9066 industrial PC system that offers a linear graphic display with full SPC functions.

Contact

MARPOSS
3300 Cross Creek Parkway
Auburn Hills, MI 48326-2758
1-888-627-7677 • 1-248-370-0404
Fax: 248-370-0621
E-mail: *marposs@us.marposs.com*
www.marposs.com

LIEBHERR GEAR TECHNOLOGY CO.

KLINGELNBERG

SIGMA POOL

Booth Number: B7016

Sigma Pool partners Liebherr and Klingelnberg will be exhibiting the following machines:

Liebherr LCS 300 CNC Generating and Profile Grinding Machine
Flexible design allows use of CBN or dressable grinding worms or wheels, *plus* an Internal grinding option

Klingelnberg P26 Precision Gear Measuring Center
Increased accuracy, simpler operation and faster cycle times with an extended range of applications, including non-gear related CMM type capabilities

Klingelnberg Oerlikon C 27 Spiral Bevel Gear Generator
Dry cutting excellence with extremely short cycle times, using advanced direct drive technology

Contact:
Liebherr Gear Technology Co.
1465 Woodland Drive, Saline, MI 48176
Phone: 734-429-7225 • Fax: 734-429-2294 • Email: info@lgt.liebherr.com

Liebherr LCS 300

Klingelnberg P 26

Klingelnberg Oerlikon C 27

GEAR TECHNOLOGY Booth Number: B7113

Get the Latest *Gear Technology* at the Gear Pavilion

Since 1984, the gear industry has relied on *Gear Technology* to be "The Gear Industry's Information Source," to provide top-notch technical and educational articles along with product information and news from around the world.

Like many of the gear-industry leaders you'll find at IMTS, *Gear Technology* is constantly finding new ways to improve its products to help make you more successful. In recent years, we've introduced the following innovations:

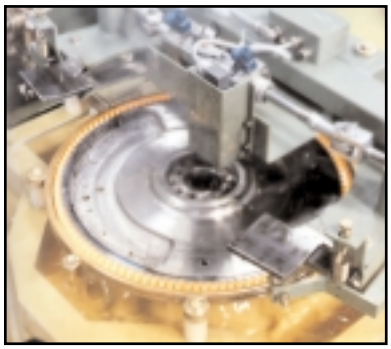
- *The Gear Industry Home Page* at *www.geartechnology.com*, where 30,000 visitors per month find the gear industry's most comprehensive directory of suppliers (going strong since 1996).
- *powertransmission.com*, where 40,000 visitors per month find manufacturers of gears, bearings, motors, couplings and other power transmission components (launched in 1997).
- *E-GT*, launched in 2003, is the electronic version of *Gear Technology*, now with more than 4,000 subscribers who can download each issue for free from anywhere in the world.

Come visit *Gear Technology* at IMTS 2004. We have some exciting news to share with you, including our latest innovations—new and better ways to serve you as the Gear Industry's Information Source.

Randall Publishing, Inc.
1425 Lunt Ave.
Elk Grove Village, IL 60007
Phone: (847) 437-6604
Fax: (847) 437-6618
E-mail: *sales@geartechnology.com*

www.geartechnology.com • www.powertransmission.com

INDUCTOHEAT
An Inductotherm Group Company



Booth Number: B7153

Inductoheat Inc., Madison Heights, Michigan, and Radyne Corporation, Milwaukee, Wisconsin will showcase the latest in gear heat treating technology at IMTS 2004, including single frequency, variable frequency and Simultaneous Dual Frequency (SDF).

SINGLE FREQUENCY gear hardening for high volume dedicated applications allows for manual tuning, while VARIABLE FREQUENCY allows for tuning with a push of a button by matching frequency to a diametrical pitch.

The SDF induction gear hardening process improves quality and efficiency, yet yields better results and higher production rates than conventional heating processes. SDF is easily integrated into new or existing manufacturing lines as a flexible workcell.

In addition, Inductoheat and Radyne feature a fully functioning metallurgical laboratory and aftermarket support. They also produce induction scanners for general purpose heat treating and the Flexitune® induction heating power supply.

INDUCTOHEAT
An Inductotherm Group Company

RADYNE
An Inductotherm Group Company

Inductoheat and Radyne are Inductotherm Group companies. They will be at booth B-7153 near the Gear Pavillion.

Inductoheat, Inc.
Madison Heights, MI
Phone: 248-585-9393
Internet: www.inductoheat.com

Radyne Corporation
Milwaukee, WI
Phone: 414-481-8360
Internet: www.radyne.com

KAPP GROUP

The best will be there.

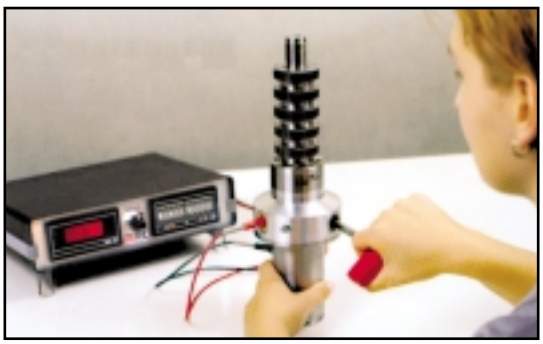
See what s behind the door at Booth B-6931

2870 Wilderness Place
Boulder, CO 80301
www.kapp-usa.com
Ph: 303-447-1130
Fx: 303-447-1131

Euro-Tech Corporation

IMTS Booth Number: E-2672

New Hydraulic Expansion Gear Arbor System

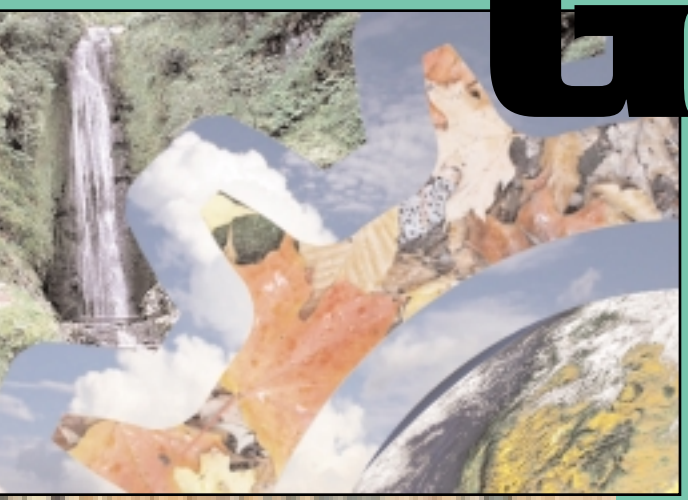


MyTec GmbH, a hydraulic expansion clamping tool manufacturer located in Germany, is pleased to introduce the new "Power Control" system for highly repeatable clamping of gears or thin-wall parts. This system consists of an internal pressure transducer and a digital readout. While all MyTec hydraulic tools are rupture proof when expanded without a part, the addition of a "Power Control" unit assures extremely repeatable clamping of thin-wall parts without distortion. The system is extremely simple to use with the operator attaching 2 magnetic "paddles" to the arbor and actuating up to a prespecified limit on the DRO. For more information, contact Euro-Tech Corporation at (262) 781-6777 or *www.eurotechcorp.com.*

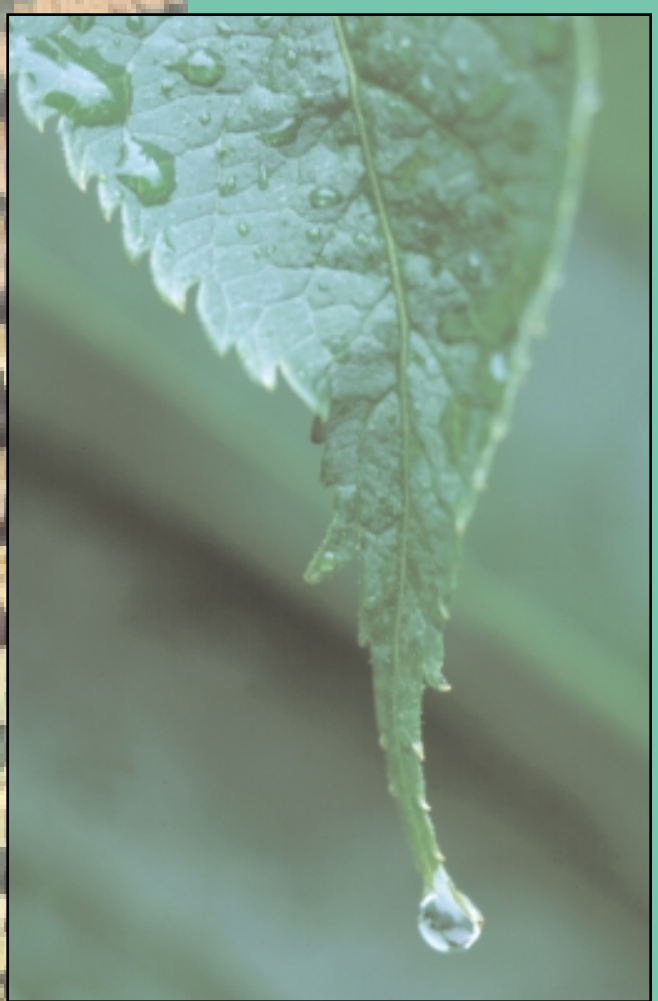
euro • tech

Contact:
N48 W14170 Hampton Ave.
Menomonee Falls, WI 53051
Phone: (262) 781-6777
Fax: (262) 781-2822
www.eurotechcorp.com
info@eurotechcorp.com

Greener Gears



Companies around the world are learning to embrace the environment, and the gear industry is no exception. This special section takes a look at how some gear manufacturers are doing their part to conserve resources, preserve and protect the environment, and give back to the land. What we've found is that adopting environmental measures is far more than just good corporate citizenship. For many gear industry companies, good environmental practices also turn out to be good for the bottom line.



Enviro-Friendly Gear Manufacturing

How Fairfield Manufacturing is gaining recognition, saving money and creating a safer workplace by minimizing the impact of its operations on the environment.

"Our goal is zero discharge," says Bob Morton.

Over the last eight years, Fairfield Manufacturing has made great strides toward that goal—and along the way, the Lafayette, IN-based gear manufacturer has won some prestigious environmental awards.

In recent years, Fairfield has stepped up its commitment to mitigating environmental impacts. "Where we've really made our gains is in the reduction of air pollution and hazardous waste and landfill disposal," says Morton, who is Fairfield's director of environmental, health and safety affairs.

Recently, Fairfield replaced a copper plating process with a non-toxic, water-based stop-off paint for masking parts before heat treating. The old process generated 25,000 pounds of cyanide-contaminated waste per year, which was hazardous and expensive to properly dispose of.

The new process doesn't generate hazardous waste. "The health hazard is very low," Morton says.

The changes helped Fairfield win the 2002 Indiana Governor's Environmental Excellence Award.

In addition to eliminating hazardous waste, replacing the copper plating process had other benefits. One of those was energy conservation. Copper plating used approximately 25,000 kilowatt hours of energy annually, according to the award application documents filed by Fairfield. Copper plating also required multiple steps and pieces of heavy equipment. The new process, on the other hand, simply involves hand painting the portions of the parts the customer doesn't want heat treated. The result is that all of that energy—and its associated costs—has been saved.

The new process saves money for other reasons as well. "It's actually probably a little cheaper," Morton says, "because of what we save on the expense of the disposal of the hazardous waste."

Finally, from a health and safety standpoint, there isn't a risk of employees being exposed to the toxic copper cyanide. "And that was a big reason to drive this as well," Morton says.

Fairfield is also active in conserving resources, and the company has an extensive recycling program. "We recycle traditional paper, cardboard, glass, scrap steel, wood pallets and aluminum cans," Morton says.

Also, Fairfield buys recycled raw materials whenever possible. Most of Fairfield's gears are made from recycled raw materials, including steel castings, forgings and rolled barstock that are manufactured from scrap steel.

Moreover, Fairfield has internalized its recycling efforts. "Employees are familiar with our recycling efforts. They're all encouraged to recycle," Morton says.

For its recycling efforts, Fairfield won the 1999 Indiana Governor's Recycling Award.

Not all of Fairfield's environmental, health and safety measures have economic benefits. In cases, like recycling, which Morton says doesn't really pay off economically, "It's about being a good corporate citizen."

To bring about these measures, Fairfield evaluates all of the company's processes for their environmental impact. Other measures have included eliminating an alcohol-based cleaning process with a water-based, ultrasonic cleaning process, replacing degreasers that used toxic solvents with washers that use soap and agitation, and eliminating some of the cooling systems on several machines that used fluorocarbons.

"We're always evaluating our processes to try and come up with creative ways we can prevent additional pollution or minimize the generation of waste," he says.

For more information:
Fairfield Mfg. Co. Inc.
U.S. 52 South
P.O. Box 7940
Lafayette, IN 47903-7940
Phone: (765) 772-4000
Fax: (765) 772-4001
www.fairfieldmfg.com

ITAMCO's Energy Source: The Wind?

"Wind power is another way we can be a responsible corporate citizen"
—David K. Neidig, VP Marketing, ITAMCO.

For more information:
ITAMCO
6100 Michigan Road
P.O. Box 399
Plymouth, IN 46563-0399
Phone: (574) 936-2112
Fax: (574) 936-7224
E-mail: *dkneidig@itamco.com*
Internet: *www.itamco.com*

Good corporate citizenship has led ITAMCO to recycle its metal chips and industrial fluids and to restore 350 acres as woodland and wetland. Now that citizenship—with a practical edge—is leading the gear manufacturer toward wind-generated electricity.

The company, 90 percent of which is Indiana Tool-Indiana Gear, studied its bills and realized it could obtain electricity more cheaply from wind turbines than from a conventional power grid.

"Utility cost savings is our main goal," says David K. Neidig, ITAMCO's vice president–marketing. But, he adds: "Wind power is another way we can be a responsible corporate citizen."

So ITAMCO, based in rural Indiana, near Plymouth, applied to the United States' Federal Aviation Administration to build a temporary tower to test wind force and speed.

ITAMCO must test the winds at its factory for 12 months to determine whether the needed Class 5 winds are consistently present.

If the wind data looks promising, the company can seek wind turbine bids after about six months and can start obtaining permits for installing wind turbines.

ITAMCO doesn't know yet how many and what size of turbine it would use, but it expects to spend about $1.5 million to install 1.5 megawatts of capacity.

Neidig estimates the turbines would pay for themselves in about seven years.

After that, how much would ITAMCO save as on its electricity bills?

"Basically 100 percent," Neidig says.

The company employs about 75 people and operates more than 100 electrically-powered machine tools in a 100,000-square-foot factory for producing metal parts. Half of the machine tools are used to manufacture gears and gear drives.

ITAMCO would locate the turbines on the land it owns next to its factory. The land includes 350 acres that ITAMCO restored in '02 as woodland and wetland.

"We have taken a 750-acre row-crop farm of corn and soybeans and transformed it into a conservation paradise," Neidig says. "We have reforested 300 acres into a hardwood plantation, 50 acres into wetlands, and still have a patchwork of 350 acres of crops lined with windbreaks and wildlife shrubs to promote soil conservation."

ITAMCO restored the land by working with Indiana's Department of Natural Resources and with the Fish and Wildlife Service of the U.S. Interior Department.

"It is all part of our commitment to good stewardship," Neidig says.

ITAMCO has manufactured wind turbine gears and gear drives for about 10 years, but it hasn't thought about whether it would manufacture parts for its own wind turbines.

"For us, those two issues are completely separate," Neidig says.

ITAMCO is still waiting for the FAA's decision, though. The company is also working with various state agencies on the turbine project.

Neidig says the process takes 2–3 years, from start (applying to the FAA) to finish (having wind turbines operating and supplying electricity).

Tips for Using Aqueous Solutions

By David Farmer,
Director of Facilities & Equipment, ACR Industries

Using water-based fluids in your shop can be an environmentally friendly and cost-saving measure. Here are some tips to make sure your parts and equipment are protected against corrosion—without using expensive and environmentally hazardous solutions.

Summer is here, along with the joys it can bring—hot, humid days to relieve winter's sting . . .Wait a minute. Heat and humidity—can't they create corrosion nightmares for gear manufacturers? Yes they can. Combine these seasonal elements with aqueous parts washing and aqueous-based machine coolants, and the nightmares intensify. Or do they?

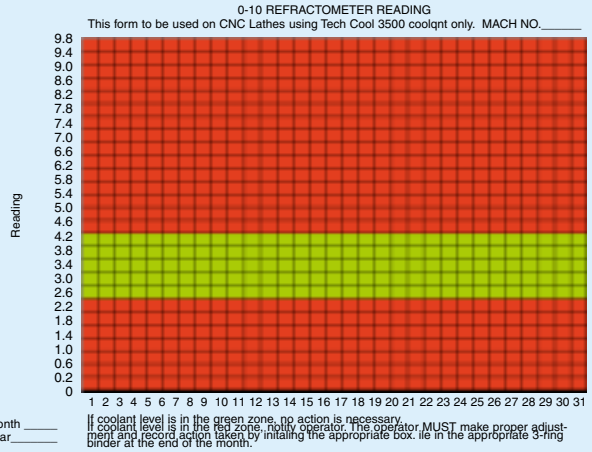
Changes in environmental law and corporate concern for the environment have encouraged many to migrate to environmentally friendly, non-hazardous, aqueous parts washing and machining fluids. Aqueous fluids can have many benefits. They can be less expensive to purchase. They can be stored as concentrates, requiring less storage space. Their use can reduce hazardous waste generation and liability. There is less product carry-off in the manufacturing cycle. They can be recycled on-site by many manufacturers. Concentrations can be modified to meet specific machining or parts washing needs. The list of benefits is impressive, but what about the corrosion problem?

One common way to prevent corrosion is to apply an oil film—preferably one with excellent water-displacing properties. This method is effective, but there are lower-cost—and more environmentally friendly—methods available to manufacturers.

Machining Fluids

Properly selected aqueous-based machine coolants work well as long as they have the required properties. They should have the right amount of lubricity for the task at hand, should be formulated to carry off heat and should be user friendly. These products should not dye or stain the parts. All of these properties can be achieved with aqueous solutions, but only if they are mixed correctly and the systems rigorously maintained.

Mixing water and concentrate becomes an easy task if a proportioner is used. These devices are installed in drums or smaller containers of concentrate. Water pressure is applied, and as it passes over the concentrate port, it draws the concentrate into the water flow, creating a mixture proportionate to the metering orifice installed. Water pressure and flow must be kept at a minimum level to operate these devices. Mixture concentrations will vary widely should



Bacteria can grow in the tramp oil, so it's important to keep the sumps clean and to periodically empty them to remove contaminants and replenish the fluid.

either pressure or flow be off. Facilities that experience low water pressure can add a booster pump to maintain needed water flow and pressure.

Mixture concentrations should be verified using a refractometer.

ACR WASHER WEEKLY INSPECTION LOG/CHECKLIST

UNIT ID:PW01-GRYMLL DATE:

ITEM	DESCRIPTION	INSPECTOR	READING	PASS	FAIL
1	HAVE FILTERS BEEN SERVICED?				
2	RECORD PRESSURE GAGE READING				
3	ANY MECHANICAL PROBLEMS?				
4	RECORD pH READING				
5	CONDITION OF WASH FLUID				
6	ANY ELECTRICAL PROBLEMS?				
7	RINSE WATER CONDITION				
8	UNIT CLEANLINESS				

NOTE 1: pH MUST BE BETWEEN 10.5 AND 11.5
NOTE 2: RECORD ANY FAILED ITEMS ON MWO PM#M0041

Figure 2.

Initial selections of proportioner orifice metering may require modification, since water in a solution will evaporate more rapidly than concentrate, which causes the strength of the coolant to increase. Selecting the proper orifice will slow this process. For employees handling the product often, too strong of a mixture can lead to dermatitis. Weak solutions lead to poor machining properties, reduced tool life and corrosion. Maintaining the correct balance is important.

It's also important to inspect each coolant sump daily and to record and correct any deviations from expected norms. Figure 1 shows one method of recording actual refractometer readings and adjustments. Green indicates that the coolant mixture is within functional limits. Red indicates that the coolant mixture is out of tolerance, and that more concentrate or more water is required to rebalance the mixture. Keeping this chart or its equivalent current is critical to the success of the machining process.

Maintaining the coolant will extend its life. It's especially important to keep it oil free. Many manufacturers use coolant sump oil skimmers for tramp oil removal. Tramp oil is often deposited in coolant tanks from way lubrication runoff and hydraulic leaks. Bacteria can grow in the tramp oil, so it's important to keep the sumps clean and to periodically empty them to remove contaminants and replenish the fluid. Should you experience corrosion problems during the machining portion of your operation, contact your coolant manufacturer. Corrosion inhibiting additives are available.

Part Cleaning

Part cleaning using aqueous fluids presents concerns similar to those found during the machining processes. Proportioner-controlled mixing of concentrate and water produces good results, and again, proper orifice selection is required to compensate for evaporation. For commonly used base solutions (a solution in which the pH is greater than 7) the recommended pH level is between 10.5 pH and 11.5 pH. A weak solution (< 10 pH) will cause corrosion. A strong solution (>12 pH) can injure personnel and may not clean the parts any better than a solution mixed according to recommendations. (It is important to note that our eyes do not have the ability to neutralize base solutions. The base solution will destroy eye tissue. Always wear suitable eye protection when working with cleaning solutions. Also, be sure to rinse eyes for a minimum of 15 minutes with water if exposed to base solutions, then seek medical attention.) An oil skimmer is recommended to remove tramp oil. Changing the fluid as needed and cleaning the sump before replenishing is desirable.

Figure 3.

One added feature of parts cleaning that requires attention is heat. For optimum performance, aqueous cleaning solutions require heat. Many recommend a temperature of 145ºF. Again, maintain the cleaning solution. Use a checklist to verify conformance to required standards. Cleaning solutions can be checked weekly using the checklist in Figure 2. Your operation may

require a different inspection frequency.

Should corrosion continue, either introduce a heated aqueous-based corrosion inhibiting rinse cycle, dip the parts in an aqueous-based corrosion inhibitor rinse tank (see Fig. 3) or contact the cleaning concentrate manufacturer regarding corrosion inhibitor additives that can be added to or formulated in the cleaning solution.

Waste Water

Now that you've taken the environmentally friendly route, what are you going to do with the water-based waste product from machine and parts cleaning sumps?

There are many options available. Machine coolants, depending on the volume used, can be recycled in-house or by the vendor. Recycling is the most cost-effective method, as long as the number of coolant types is kept at a minimum. Coolants can also be processed in a waste treatment system, chemically or through membrane technologies, either in-house or through a vendor.

Spent cleaning solutions can be neutralized in a waste treatment system by adding an acidic compound, such as aluminum sulfate. This additive will adjust the pH to a near-neutral state. Then waste waters can be processed either chemically or through membrane technologies. Treated waters may be re-used to make floor scrubber soap or mop water. Given the appropriate permitting and testing, the treated water can then be placed in sewers—depending on cost benefits. Many options are available for processing waste aqueous fluids, if the fluids are diligently separated from hazardous materials throughout their life cycles.

At ACR, waste water that is produced by temper (nital) etch inspection and vibratory deburring is treated and recycled chemically. The temper etch inspection waste stream is turned into mop water, and the deburring waste stream is re-used following ultraviolet light treatment a maximum of three times. Parts washing waste streams are recycled and used for floor cleaning. A program is currently under way to consolidate coolant types for recycling. Water use has dropped dramatically as a result of these efforts and will fall sharply again as coolant recycling becomes available following product consolidation (see Figs. 4–5). Some waste waters are hauled to off-site treatment centers by licensed waste haulers. Those waters are treated and released at a cost to ACR of 0.12 cents per gallon.

Great—we have processes and procedures in place to prevent corrosion in the manufacturing cycle. Now let's get back to enjoying that summer weather!

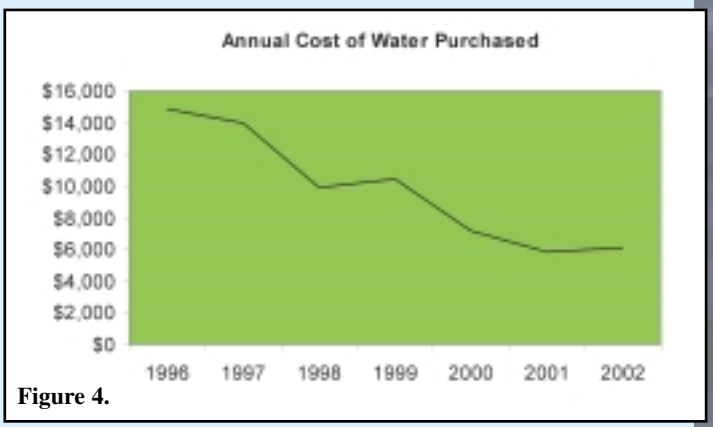


Figure 4.

ACR Industries Inc. is a Triumph Group Inc. company. Located in Macomb, Michigan, ACR is a supplier of complex gear assemblies, detail gears, and an array of components servicing the aerospace industry. Triumph Group Inc., headquartered in Wayne, Pennsylvania, designs, engineers, manufactures, repairs and overhauls aircraft components and industrial gas engine components and accessories. The company serves a broad, worldwide spectrum of the aviation industry.

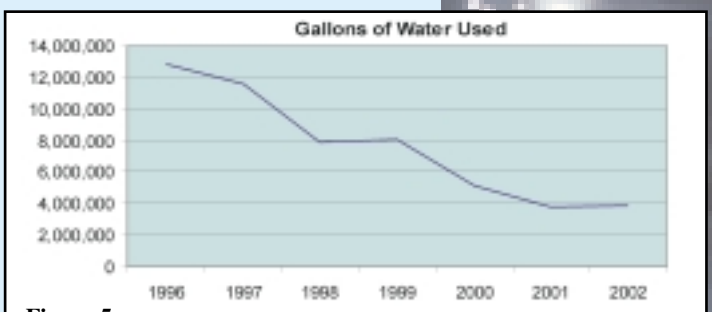


Figure 5.

For more information:
ACR Industries Inc.
15375 23-Mile Rd., Macomb, MI 48042-4000
Phone: 586-781-2800 • Fax: 586-781-0152
E-mail: *sales@acrind.com* **• Internet:** *www.acrind.com*

National Lab Looks at New Geared Drivetrain to Aid Wind Energy Industry

The National Renewable Energy Laboratory is testing a prototype wind turbine drivetrain that includes an uncommon part in its planetary gearbox: an internal double helical ring gear with a 60-inch pitch diameter.

"The prototype is based on extensive trade study," says Christopher Walford, a senior engineer at Global Energy Concepts LLC, an American consultancy on renewable energy technology. Located in Kirkland, Washington, Global Energy Concepts is NREL's contracted agent for performing this study.

The consultancy is conducting the study in conjunction with Powertrain Engineers Inc. of Pewaukee, Wisconsin, and DRS Electric Power Technologies Inc. of Hudson, Massachusetts.

According to Walford, the study included eight alternative topologies available for wind turbine drivetrains. The study was created to investigate wind turbines that would be used for utility-scale energy production, to reduce their cost of energy. Given the utility-scale focus, the designs were for 1.5 MW drivetrains. Today, new utility-scale wind farms commonly use wind turbines able to generate at least 1.5 MW.

Walford says the size of wind turbine that can be made with an internal double helical gear depends on the gear form-grinding machine.

The gear industry can form grind internal double helicals with pitch diameters even greater than 60 inches. As an example, Walford mentions Höfler machines able to form grind an internal gear with an 80-inch pitch diameter—"There's a few of those in the world."

However, he adds that double helicals are somewhat new to wind turbines and "definitely a challenge."

But if there's a market for the gears, there are gear manufacturers who would buy the machines to meet the market's demand.

If cost efficiency is a guide, then the market should materialize.

"Everybody wants more efficiency," Walford says, "that's the name of the game."

The NREL study compared nine conceptual designs of 1.5 MW drivetrains, eight designs compared against a widely-used baseline design.

Global Energy Concepts estimated cost and operational aspects of the designs and chose for manufacture the drivetrain whose cost of energy (COE) was the lowest of the eight. The designs' COEs took into account annual net energy production, total cost and levelized replacement costs. The chosen design's annual net energy production was the highest, total cost the 3rd lowest, and levelized replacement costs the 3rd lowest.

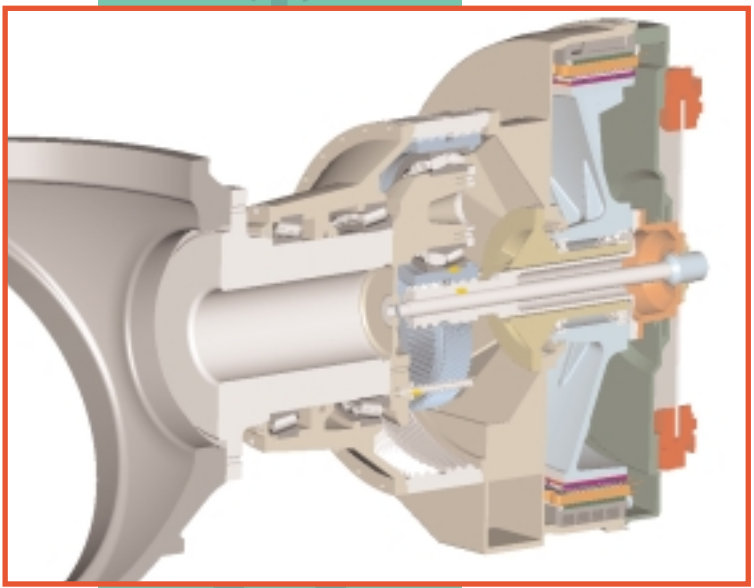
The chosen drivetrain included a single-stage planetary gearbox, a permanent magnet rotor and a permanent magnet generator.

The prototype's COE estimate was 13 percent lower than the baseline COE. Global Energy Concepts also scaled the prototype design to a 3 MW version. The drivetrain's COE estimate hardly changed when scaled to that size.

As for wind turbine demand, America's wind energy industry boomed again in '03. The United States installed a near record 1,687 MW of new capacity. Hundreds of wind turbines, with hundreds of planetary gear drives, were installed in states like California, Illinois, New Mexico, Minnesota, Ohio and Texas.

Global Energy Concepts is scheduled to complete its work in December, depending on whether it can get time in the National Weather Technology Center's dynamometer for load testing. The study will be in the public domain, to ease its entry into the wind turbine manufacturers' world.

The report on the study's first phase, design and comparison, is available at *www.nrel.gov/docs/fy03osti/33196.pdf*. There won't be a report on the just-completed second phase, the prototype's manufacture, but there will be a report after the study's final phase, after Global Energy Concepts completes its load and functional testing.

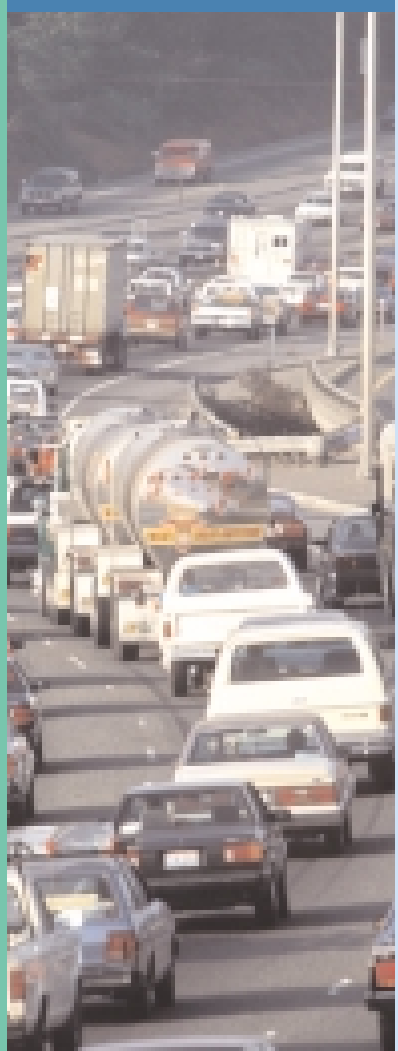


Five Feet in Diameter—An internal double helical ring gear lays at the center of a prototype 1.5 MW wind turbine designed by Powertrain Engineers Inc., then manufactured by Brad Foote Gear Works Inc. of Cicero, Illinois.

Global Energy Concepts LLC
5729 Lakeview Drive NE
Suite 100
Kirkland, WA 98033-7340
Phone: 425-822-9008
Fax: 425-822-9022
gec@globalenergyconcepts.com
www.globalenergyconcepts.com

ISO 14001: Coming to a Gear Shop Near You

Although it's been published for eight years and is very important in the auto industry and outside the United States, ISO 14001 registration is still a project only a few American gear shops have taken on.



Although it's been published for eight years and is very important in the auto industry and outside the United States, ISO 14001 registration is still a project only a few American gear shops have taken on.

ISO 14000 is a family of environmental management standards. The group itself encompasses chapters of guidance documents and standards on specific aspects, such as environmental performance evaluation, as well as ISO 14001, which specifies the requirements for an environmental management system. To be registered or certified to ISO 14001, companies must demonstrate to an independent registration body that they are in compliance with all the rules laid out in ISO 14001.

While it can be applicable to any company, ISO 14001 is especially important for manufacturing operations. Factors like electricity usage, cooling fluids and dozen of others are evaluated to maximize environmental safety.

By Definition

Similar to ISO 9001:2000, the ISO 14001 family of international standards is a voluntary system for management that allows businesses to identify the company's impact on the environment and a framework to improve its environmental performance.

ISO 14001 was originally published in 1996 and is currently undergoing its first revision. While it did grow out of ISO 9000, there is a fundamental difference. Consultant Jim Highlands of Management Systems Analysis of Limerick, PA, explains the growth process between the two standards.

"ISO 14001 is a transition from measuring what's coming out of the organization to having a set of controls to preclude that result," he says.

According to the ISO website, the focus for ISO 14001 is on the process rather than the product. Requirements are centered around assuring that the product will have the least harmful effect on the environment at any stage in its life cycle.

Hot International Sensation

A European trend that's been implemented in 113 countries worldwide, the adopting of ISO 14001 has not taken off quite as quickly in the United States. Currently, the U.S. ranks 6th in the world as far as number of registered companies.

Part of the reason for this is geographical, explains Regina Thompson, Louisville Forge & Gear Works' environmental management representative.

"The U.S. has been slow with ISO 14001. In Europe, there's such a massive population per square foot, but, in the States, there is still a lot of open territory to dump waste, so the motivation isn't the same," she explains.

A number of those American companies that are certified to ISO 14001 took the plunge at the encouragement of their parent companies. That was the case with Louisville Forge of Georgetown, KY, whose parent company is Aichi Steel Corp. of Aachi-ken, Japan. The company, a Tier 2 supplier to Toyota, primarily manufactures forgings, crankshafts and ring gears.

The driving reason behind their ISO 14001 certification was the automotive requirement, but Thompson says it's also a step that more Americans are taking.

"It is growing in this country. More U.S. companies are realizing that it's better to jump on the bandwagon now than to wait for it to become an EPA mandate," she says.

By the end of 2002, a total of 49,462 ISO 14001 certificates had been issued. The data, accessible online at *www.iso.org*, suggests that ISO 14001 is growing at a rapid rate. By December 2002, North America accounted for 8.2% of the new certificates granted, while Europe took 47%, and 36% of the new ISO 14001 companies were in the Far East.

Help from the Outside

Attaining ISO 14001 status is a long process and many companies find it easier to outsource that task. Greg Marchand, president of Great Bay Consulting of Lyndon Center, VT, has worked on ISO with large corporations like Toyota Motor Sales down to a workplace with a single employee. For the average company with 200 employees, he says it usually takes about a year to move through the certification process.

"It's not for the faint of heart," says Marchard. "It can be done in a shorter time, depending on how documented the processes are."

Once hired, the consultant works on-site to ensure that the entire system is in place before an auditor arrives.

However, it is possible to pass the audit without the presence of a third party. Implementing the environmental management system usually falls under the jurisdiction of a quality control manager.

Whoever prepares the company for the audit, it's an independent third party registrar that conducts it and issues the ISO certificate. Worldwide there are 750 registrars, popular names being DNV, TUV and BVQI. For a more complete list of registrars, visit *www.rabnet.com*.

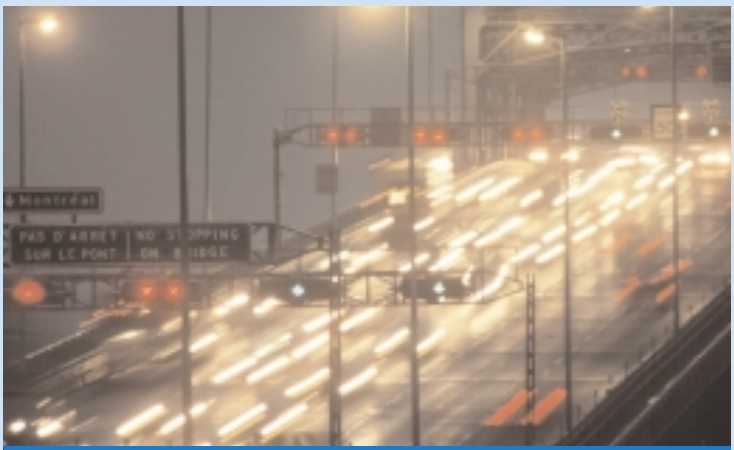
"A lot of companies fail the initial audit," says Marchand. "Then you have to do a lot of fast talking to get the registrars to come back in. Generally, for the company with 200 employees, it can cost upwards of $20,000 for the initial (certification) and around $6,000–$8,000 for annual maintenance."

For Al Descoteaux, director of operational excellence for Nypro Inc., a plastic injection molding company that manufactures plastic gears, getting the ISO 14001 registration in 1999 was worth every penny.

"Customers are becoming increasingly concerned with the environment. It's been an asset in gaining new business and accounts and establishing ourselves as a leader because less than half of our competitors are doing it," he says. "It keeps us out of trouble with the EPA too, which ultimately helps our bottom line."

In the coming years, this may be an investment that gear companies will have no choice but to make. Public demand will force companies to start the registration process.

"Customers think it's a great thing. It forces you to document your current processes and shows environmental responsibility," concludes Marchard.



Tell Us What You Think . . .
Send e-mail to *wrs@geartechnology.com* to
- **Rate this article**
- **Request more information**
- **Contact the companies mentioned**
- **Make a suggestion**

Or call (847) 437-6604 to talk to one of our editors!

Load Carrying Capacity of Screw Helical Gears with Steel Pinions and Plastic Wheels

Wolfgang Predki and Peter Barton

Management Summary

There is an increasing significance of screw helical and worm gears that combine use of steel and plastics. This is shown by diverse and continuously rising use in the automotive and household appliance industries. The increasing requirements for such gears can be explained by the advantageous qualities of such a material combination in comparison with that of the traditional steel/bronze pairing.

In order to develop an optimal design of steel/plastic gears in the future, a comprehensive and systematic calculation method has been developed. It enables the designer to calculate the operating life and the load capacity for diverse operating and design parameters. The calculation method is based on several experimental and theoretical considerations, by which the influence of various parameters on efficiency and damage mechanisms is tested.

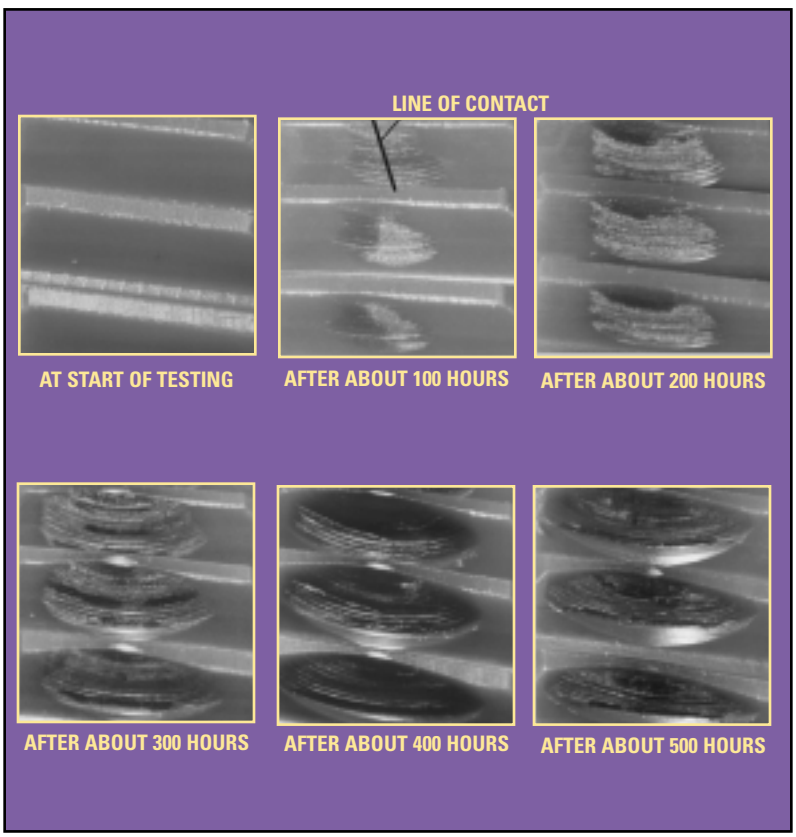


Figure 1—Wear.

Abstract

The development of a new calculation process has for the first time made it possible to calculate the load carrying capacity of screw helical gears with steel pinions and plastic wheels. This development has laid the foundation for a technically and economically optimized design of future gear unit generations. The calculation process is based on numerous theoretical and experimental investigations.

Introduction

Screw helical gears in which the wheel is made from plastic and the pinion which engages a cylindrical worm is made from steel are being used increasingly in drive engineering. For example, gear units of this type are used in the automotive industry, in drives for electric window lifters and windscreen wipers, in electric seat adjustment systems, and are used in domestic appliances, such as the electrical bread slicer.

These applications are making use of the advantages offered by this material combination in comparison to a conventional steel/bronze pairing. The advantages include reduced weight, lower manufacturing costs and good vibration damping characteristics. Other advantages are the reduced lubrication requirements and the high level of electrical insulation.

These advantages could not be exploited to the optimum extent in the past because the load carrying capacity of screw helical gears with steel pinions and plastic wheels could only be estimated, not calculated accurately (Refs. 5–6).

The objective of this research project, only the salient points of which are presented here, was therefore to conduct theoretical and experimental investigations as a means for analyzing the load carrying capacity of these gear units. This would allow for development of a calculation method and a computer program, which for the first time would enable designers to accurately calculate and, in the final analysis, optimize the load carry-

ing capacity and operating life of the gear units.

This paper not only presents a means for calculating tooth coefficients of friction, it also presents a means for estimating permitted tooth temperatures and allowable extent of wear. A detailed presentation of this topic can be found in Reference 1. This reference deals in greater depth with load carrying capacity at the tooth root and with pitting, as well as the temperature fluctuations in the lubricant.

Gear Damage

Various types of gear damage occurred during the numerous experiments conducted to calculate the load carrying capacity of the aforementioned screw helical gears. These damages led to the total failure of the gear units.

The series of photographs in Figure 1 show tooth flanks at various stages of an endurance test, starting at the beginning of the test and after approximately 100, 200, 300, 400 and 500 hours of running. As well as the position of the line of contact, the propagation of the contact pattern can be seen clearly. This indicates the increasing degree of wear.

Figure 2 shows how the plastic teeth break along the addendum circle of the worm. As a result of the notch effect, the crack either starts in the middle of the tooth or on the addendum circle of the worm at the level of the gear's datum circle.

The deformation of the gear teeth results in a pinching effect within the gearing, as shown in Figure 3.

Excessive temperatures lead to melting of the gearing, as shown in Figure 4.

Also, pitting, as seen in Figure 5, leads to vibration of the gear unit, causing additional undesirable dynamic forces.

Analysis of Load Carrying Capacity

An extensive analysis of the load carrying capacity is needed in order to preclude the aforementioned damage mechanisms. As a result, the individual damage modes are incorporated into the newly developed equations.

Ascertaining the average tooth coefficient of friction μ_{zm}. The analysis of the load carrying capacity starts by ascertaining the average tooth coefficient of friction μ_{zm}. This determines the losses in the gearing and is used for ascertaining the gearing power loss P_{VZ}.

In Figure 6, the diagram shows sample μ_{zm} values for various speeds and torques. These are calculated on the basis of torque and speed measurements during the tests, with consideration for losses in bearings and on seals on the basis of the manufacturer's figures.

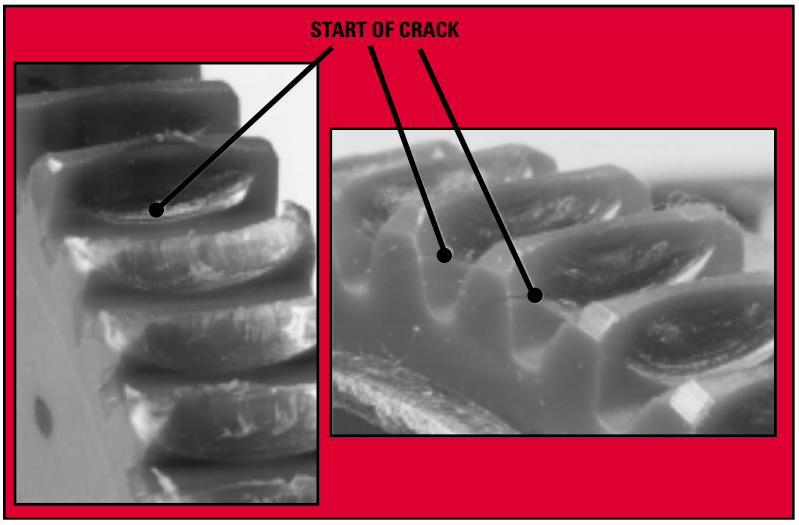


Figure 2—Tooth break.

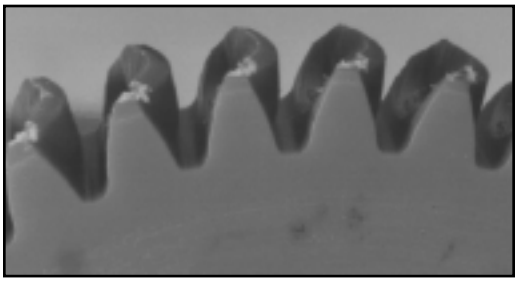


Figure 3—Deformation of the gear teeth.

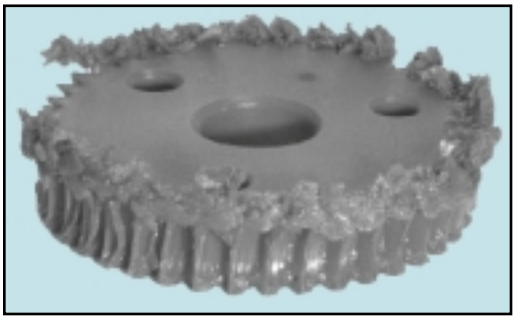


Figure 4—Melting.

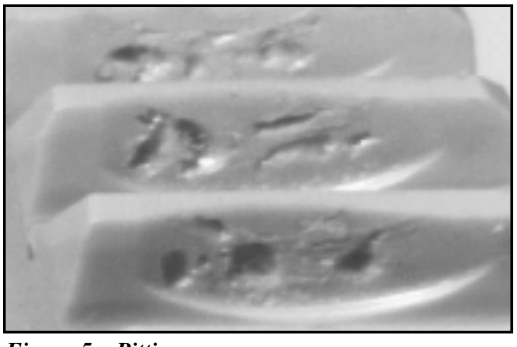


Figure 5—Pitting

As can be seen, the values for the average tooth coefficient of friction increase as the speed increases and the torque is reduced.

The curves shown are the results of regression calculations. The equations described for the average tooth coefficient of friction μ_{zm} are listed

Prof. Dr.-Ing. Wolfgang Predki
is the head of the chair of mechanical components, industrial and automotive power transmission at Ruhr University, located in Bochum, Germany. The chair's research focuses on wear optimization of worm gears, on plastic and sintered worm gears and on optimization of bronze gears.

Dr.-Ing. Peter Barton
is a department head at SEW-Eurodrive GmbH & Co. KG in Bruchsal, Germany. His department performs research & development for industrial gears, specifically helical, bevel-helical and planetary gearboxes, as well as customized designs. At SEW, he's performing basic research in Spiroplan® gearboxes, which are similar to the screw helical gears discussed in this paper. The paper itself summarizes parts of his Ph.D. dissertation.

as Equations 1 and 2 (Ref. 1). The datum circle is used for calculating the average tooth coefficient of friction in screw helical gears in a similar manner to the process for worm gear units (Ref. 2). The sliding speed at the datum circle is then calculated according to DIN 3996 (Ref. 3).

$$\mu_{zm,\mathrm{PEEK}} = 0.0549 + 0.0334 \bullet v_{gm}^{\,0.4817} + 0.2528 \bullet T_2^{\,-2.2462} - 0.027 \bullet \left(\frac{v_{gm} \bullet T_2}{a}\right)^{1.1323} \quad (1)$$

$$\mu_{zm,\mathrm{PA4.6}} = 0.0907 + 0.0314 \bullet v_{gm}^{\,0.4485} + 0.1904 \bullet T_2^{\,-2.1227} - 0.0598 \bullet \left(\frac{v_{gm} \bullet T_2}{a}\right)^{0.3902} \quad (2)$$

$\mu_{zm,\mathrm{PEEK}}$: Average tooth coefficient of friction for the PEEK material

$\mu_{zm,\mathrm{PA4.6}}$: Average tooth coefficient of friction for the PA4.6 material

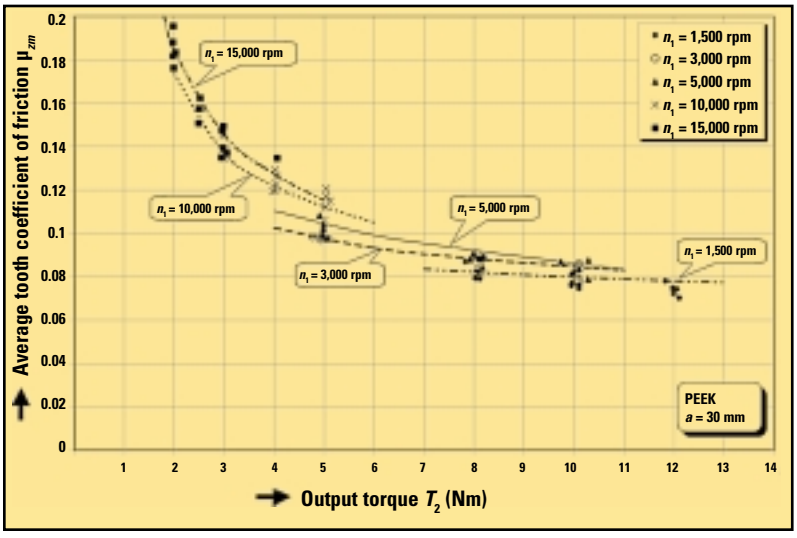


Figure 6—Average tooth coefficient of friction μ_{zm}.

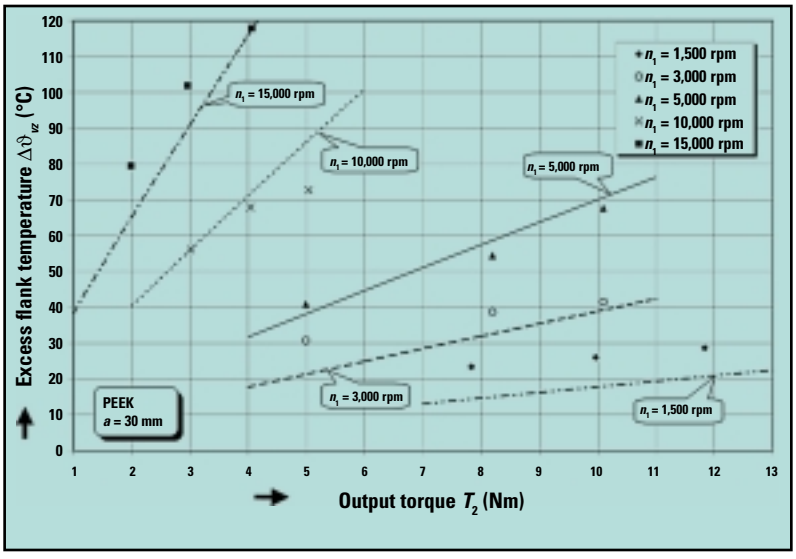


Figure 7—Excess flank temperature.

v_{gm} : Sliding speed at the datum circle in m/s

T_2 : Output torque in Nm

a : Center distance in mm

Temperature equations. A preliminary thermal calculation for screw helical gears with steel pinions and plastic wheels forms the basis for a more accurate investigation of the individual damage mechanisms.

It is possible to assess the functional capabilities of the lubrication system by determining the sump temperature; the gear mass temperature provides information about the strength of the gear material in the tooth core, while the flank temperature makes it possible to analyze the material strength at the surface of the flank.

Since the procedures for ascertaining the individual temperatures are practically identical, only the process for ascertaining the flank temperature ϑ_{VZ} is shown here by way of example.

The flank temperature ϑ_{VZ} is the maximum temperature which arises in the gear unit, because it is measured directly at the principal point of heat generation, namely on the tooth flank. It is composed of the sump temperature ϑ_S and the excess flank temperature $\Delta\vartheta_{VZ}$. The approximation equations for the excess flank temperature are listed in Equations 3 and 4; these are dependent on the material.

$$\Delta\vartheta_{VZ,\mathrm{PEEK}} = 0.3866 \bullet P_{VZ} + 43{,}755.264\left(\frac{T_2}{a^2 \bullet u}\right) v_{gm}^{\,1.1938} \quad (3)$$

$$\Delta\vartheta_{VZ,\mathrm{PA4.6}} = 0.0579 \bullet P_{VZ} + 69{,}582.462\left(\frac{T_2}{a^2 \bullet u}\right) v_{gm}^{\,1.2353} \quad (4)$$

$\Delta\vartheta_{VZ,\mathrm{PEEK}}$: Excess flank temperature for the PEEK material in °C

$\Delta\vartheta_{VZ,\mathrm{PA4.6}}$: Excess flank temperature for the PA4.6 material in °C

P_{VZ} : Gearing power loss in W

T_2 : Output torque in Nm

a : Center distance in mm

u : Ratio = z_2/z_1

v_{gm} : Sliding speed at the datum circle in m/s

The gearing power loss P_{VZ} is calculated according to DIN 3996 (Ref. 3) with incorporation of Equations 1 and 2.

Figure 7 indicates that the excess flank temperature increases as the speed and torque

increase. The approximation equations for the particular materials are listed in Equations 3 and 4.

Extent of wear. Wear represents a significant mode of damage. The calculation of wear is illustrated here by way of example. The extent of wear in the normal plane δ_{wn} is introduced for the purposes of the calculation process. In the calculation model, the actual progression of the wear is replaced by a fixed running-in wear δ_{w0n} and an increase in wear δ_{dwn}, which depends on the operating time.

The extent of wear increases over time, as shown in Figure 8. Starting from zero, the wear increases rapidly during the first few hours before starting a less pronounced, almost linear progression.

The resulting calculation method is shown in Equation 5.

$$\delta_{wn} = \delta_{w0n} + \delta_{dwn} \qquad (5)$$

δ_{wn} : Extent of wear in normal plane in µm
δ_{w0n} : Running-in wear in normal plane in µm
δ_{dwn} : Increase in wear in normal plane in µm

The following equations are used for determining the amount of wear. It is first necessary to ascertain the running-in wear, followed by the increase in wear.

Running-in wear. The running-in wear is calculated using Equations 6 and 7; it is represented as a function of the Hertzian compressive load for screw helical gears at ambient temperature. At an elevated ambient temperature, the compressive load must be ascertained using the starting temperature.

Investigations have shown that it is a good idea to use the surface stress at ambient temperature because there is no temperature equilibrium and therefore no stress equilibrium established during the period in which running-in wear takes place.

The effect of the ratio is taken into account in the equations by the coefficient of the average sliding distance s^*. The Hertzian surface stress at ambient temperature σ_{Hm0S} has to be ascertained on the basis of the Niemann/Winter Theory (Ref. 4), while the coefficient of the average sliding distance s^* is ascertained according to DIN 3996 (Ref. 3).

$$\delta_{w0n,PEEK} = (2.2458 \bullet v_{gm}^{0.5206} + (0.015 \bullet \sigma_{Hm0S})^{3.8835}) \bullet \left(\frac{s^*}{44.7678}\right)^{2.3716} \qquad (6)$$

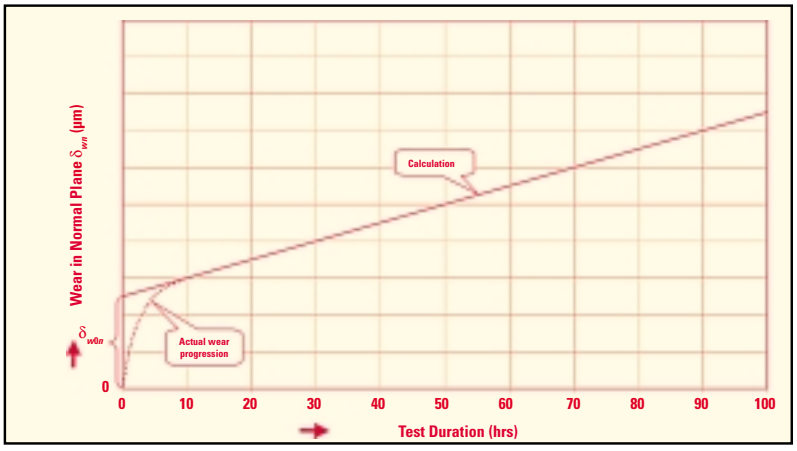


Figure 8—Extent of wear.

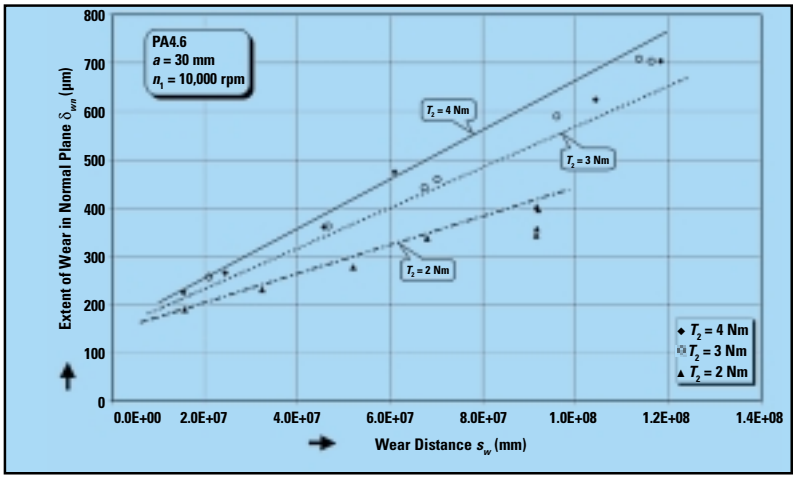


Figure 9—Wear measuring results.

$$\delta_{w0n,PA4.6} = (7.3625 \bullet v_{gm}^{1.5724} + (0.0205 \bullet \sigma_{Hm0S})^{2.9419}) \bullet \left(\frac{s^*}{45.0917}\right)^{2.3968} \qquad (7)$$

$\delta_{w0n,PEEK}$: Running-in wear in normal plane for the PEEK material in µm
$\delta_{w0n,PA4.6}$: Running-in wear in normal plane for the PA4.6 material in µm
v_{gm} : Average sliding speed at the datum circle in m/s
σ_{Hm0S} : Hertzian surface stress at ambient temperature in N/mm²
s^* : Coefficient of the average sliding distance

Increase in wear. DIN 3996 (Ref. 3) provides a calculation method for the increase in wear δ_{dwn}. This can be calculated in accordance with Equation 8 by taking the wear intensity J_w and the wear distance s_w. The wear distance s_w can be calculated according to DIN 3996 (Ref. 3).

$$\delta_{dwn} = J_w \bullet s_w \qquad (8)$$

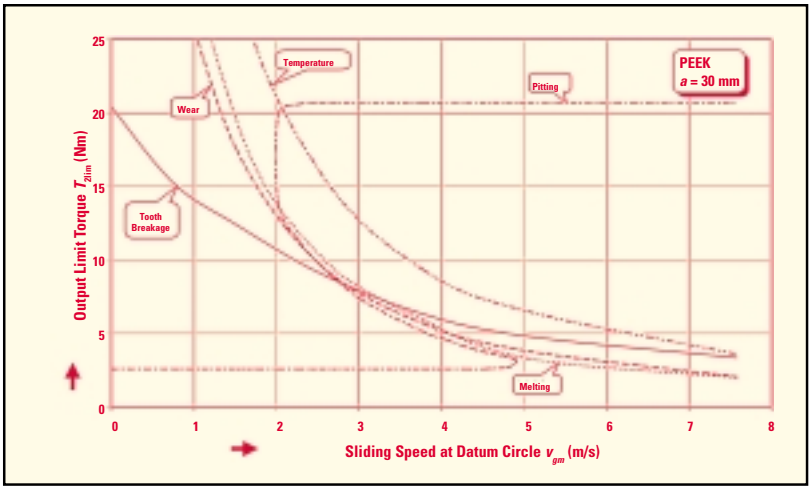


Figure 10—Output limiting torque curves.

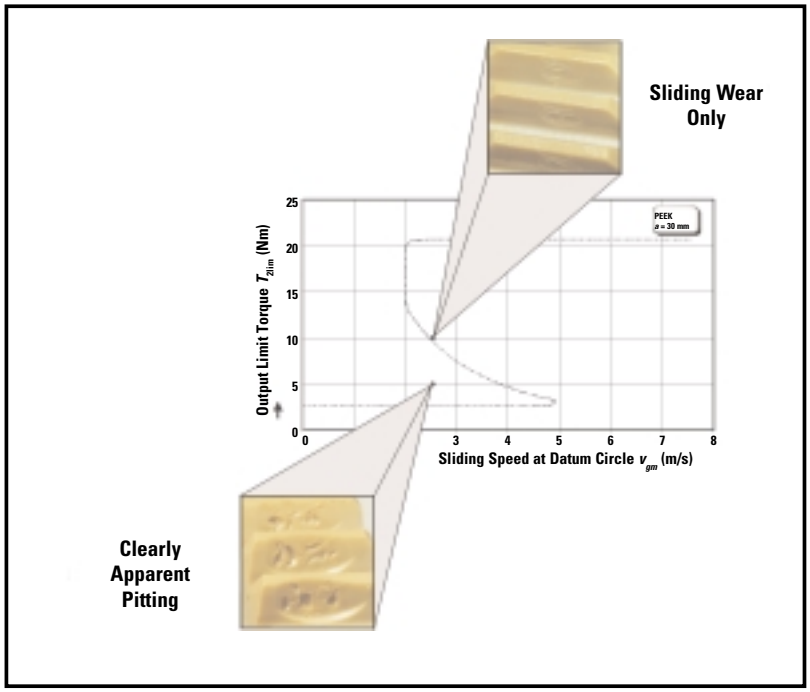


Figure 11—Pitting limit torque curve.

δ_{dwn} : Increase in wear in normal plane in µm
J_w : Wear intensity
s_w : Wear distance in mm

The wear intensity J_w depends on the Hertzian surface stress in worm gear units σ_{HmG} according to DIN 3996 (Ref. 3), the average sliding speed v_{gm}, the center distance a and the lubricant viscosity υ at operating temperature, see Equations 9 and 10.

$$J_{w,\mathrm{PEEK}} = 4.9228 \cdot 10^{-5} \cdot \sigma_{HmG}^{\,0.1717} \cdot v_{gm}^{\,-0.1952} \cdot a^{-0.5513} \cdot \upsilon^{-0.4713} \quad (9)$$

$$J_{w,\mathrm{PA4.6}} = 1.7165 \cdot 10^{-5} \cdot \sigma_{HmG}^{\,1.0843} \cdot v_{gm}^{\,0.3248} \cdot a^{-1.101} \cdot \upsilon^{-0.3866} \quad (10)$$

$J_{w,\mathrm{PEEK}}$: Wear intensity for the PEEK material
$J_{w,\mathrm{PA4.6}}$: Wear intensity for the PA4.6 material
σ_{HmG} : Average surface stress on worm gears in N/mm²
v_{gm} : Sliding speed at the datum circle in m/s
a : Center distance in mm
υ : Kinematic viscosity of the lubricant at operating temperature in mm²/s

The wear intensity increases as the compressive load increases and as the center distance and the lubricant viscosity decrease.

The wear measuring results and the approximations in Equations 5, 7, 8 and 10 are shown by way of example in Figure 9 for a screw helical gear with PA4.6 as the wheel material, a center distance of a = 30 mm and an input speed of n_1 = 10,000 rpm.

Two wear limits can be specified for ascertaining the safety margin: 1.) when a gear tooth becomes pointed, because further wear would lead to a reduction in the tooth height and 2.) excessive backlash, which is specified as $0.3 \cdot m_n$, according to DIN 3996 (Ref. 3).

Simulation with the KSG Computer Program

For the first time, the newly developed KSG computer program makes it possible for designers to simulate screw helical gears with steel pinions and plastic wheels, i.e. to calculate the load carrying capacity and operating life. Figure 10 shows examples of size a = 30 mm gear units with the PEEK material, the limit curves for the output torque as a function of the sliding speed at the datum circle v_{gm} and the damage mechanisms.

In the lower speed range, the tooth breakage damage mechanism is the limiting factor, while wear comes to prominence in the medium range. At high speed, melting is the decisive factor influencing the level of torque which can be transmitted. The temperature of the lubricant does not have a limiting effect provided the lubricant is suitable. Pitting occurs in the lower and medium speed ranges even at low levels of wear; however, this does not lead directly to failure of the gearing. As a result, pitting is not regarded as a limiting factor.

The pitting limit curve in Figure 10 differs from the other curves in terms of its shape. This is because of the non-definitive area in the medium speed range. In other words, in a gear that undergoes pitting at low torque levels, pitting can be avoided by increasing the output torque. The

reason for this lies in the considerable drop in the e-modulus of the plastic at the glass transition temperature, an effect which comes fully into play in this example.

Figure 11 illustrates this phenomenon. In this case, the pitting limit curve and the tooth flanks from two experiments are shown at the same operating time. The lower section shows a gear which was subjected to an output torque of 5 Nm and displays clearly apparent pitting. However, doubling the output torque to 10 Nm results in only sliding wear.

Conclusion

For the first time, the calculation method presented briefly here permits designers to accurately calculate the load carrying capacity of screw helical gears with steel pinions and plastic wheels. As a result, the process allows these drives to be optimized. Test rig trials conducted on size a = 30 mm and a = 65 mm gear units served to investigate the influence of various design and operating parameters on the load carrying capacity of the gear unit.

The test gear units were fitted with cylindrical worms with ground tooth flanks and wheels made from PEEK and PA4.6. The speed and torque were varied in addition to the geometries and the materials.

On the basis of the gear unit losses, it is possible as a first step to determine approximation equations for the average tooth coefficient of friction. These equations serve as the basis for temperature calculations. At the same time, static evaluation of the measured temperatures results in approximation equations for the sump, gear mass and flank temperatures. This shows that the temperatures are dependent on the gearing power losses, the output torque in relation to the center distance and the gear tooth ratio, as well as the sliding speed at the datum circle.

It is possible to determine the extent of wear on the tooth flanks on the basis of the temperature equations which were obtained. To a large degree, the extent of wear influences the load carrying capacity of the gearing.

The load carrying capacity of the tested gear units is significantly dependent on the worm speed, the torque and the material. These test parameters give rise to different gear damage. There are increased levels of pitting and tooth breakage at low speed. At high speeds, the gear unit fails due to the upper operating temperature of the plastic or the lubricant being exceeded. As a rule, gears made from PA4.6 do not have as great a load carrying capacity as those made from PEEK.

Finally, the newly developed KSG simulation program enables the user to preclude the various aforementioned types of damage and to optimally design the gear unit in view of the required boundary conditions. ⚙

This paper was presented at the VDI symposium "Maschinenelemente aus Kunststoff," held Oct. 10, 2001, in Erlangen-Nürnberg, Germany, and at the International Conference on Gears, held March 13–15, 2002, in Munich, Germany. It was also published by VDI Verlag GmbH in the conference's proceedings, in VDI report 1665. It is republished here with VDI Verlag's permission.

References

1. Barton, P. "Tragfähigkeit von Schraubrad- und Schneckengetrieben der Werkstoffpaarung Stahl/Kunststoff," Ph.D. Dissertation, Ruhr-Universität Bochum, Deutschland, 2000.
2. DIN 3975. "Begriffe und Bestimmungsgrößen für Zylinderschneckengetriebe mit Achsenwinkel 90°," Beuth Verlag GmbH, Berlin, Deutschland, July 2002.
3. DIN 3996. "Tragfähigkeit von Zylinder-Schneckengetrieben mit Achsenwinkel = 90°," Beuth Verlag GmbH, Berlin, Deutschland, September 1998.
4. Niemann, G., and H. Winter. *Maschinenelemente Band III*, 2nd ed., Springer Verlag, Berlin, Deutschland, 1986.
5. Schmidt, H. "Schneckengetriebe mit Schneckenrädern aus Hostaform," *Antriebstechnik*, Vol. 24, No. 3, March 1985, pp. 61–67.
6. VDI Richtlinie 2545. "Zahnräder aus thermoplastischen Kunststoffen," VDI-Verlag GmbH, Düsseldorf, Deutschland, January 1981.

See state-of-the-industry tools, options, and ideas at IMTS 2004.

Take your company's product development to the next level with the insights you'll find at IMTS 2004. See innovative ideas in action, examine how new and improved machinery could improve efficiency, and for the first time at IMTS 2004 – enjoy an introduction to experimental equipment and processes still in development.

Visit us at **www.IMTSNET.org** for all the latest information on the show, including news, exhibitors, and special events. **It's not too soon to mark your calendar and get ready for the future of manufacturing technology.**

IMTS 2004

International Manufacturing Technology Show

September 8–15, 2004 McCormick Place Chicago, IL USA

7901 Westpark Drive, McLean, Virginia 22102-4206 USA 800-322-4687 **www.IMTSNET.org**

July 6–9—PSA 2004. Singapore Expo Center, Halls 3 and 4. Asia's largest show is broken up in categories of rotating equipment; fluid, air and gas handling systems; water and environmental management technology; control and instrumentation; fluid power and power transmission technology. Admission is free. For more information, contact HQ Link Pte Ltd. by telephone at (65) 6534-3588 or via the Internet at *www.psa2004.com*

August 8–10—Environmental & Waste Processes 2004. Embassy Suites Pleasant Hills, Walnut Creek, CA. Session topics include environmental risk assessment, small waste to energy plant APC retrofits, air pollution control cost and benefit analysis, multipath risk assessment for waste facilities, risks associated with incineration, and biowaste composting or combustion. For registration before July 7, fees are $150 for SWPD and EED members. After that date, $200 for members and $320 for nonmembers. For more information, contact John Austin by e-mail at *jaustin@hampton.gov*.

August 9–12—Basic Gear Fundamentals Course. Gleason facility, Loves Park, IL. Individuals participate in small training groups that cover gear types and ratios, involute gear geometry, gear tooth systems, general formulae and mathematics, forming/generating and hobbing/shaping of gears, tool vs. gear tolerance, gear inspection and other related topics. $895. To register, contact Gleason Corp. on the Internet at *www.gleason.com*.

September 8–15—International Manufacturing Technology Show 2004. McCormick Place, Chicago, IL. Designed for individuals involved in any aspect of manufacturing and engineering. Please refer to *Gear Technology*'s coverage starting on page 14. For more information, contact AMT—The Association for Manufacturing Technology on the Internet at *www.imtsnet.com* or by telephone at (703) 893-2900.

Tell Us What You Think . . .
Send e-mail to *wrs@geartechnology.com* to
- **Request more information**
- **Contact the organizations mentioned**
- **Make a suggestion**

Or call (847) 437-6604 to talk to one of our editors!

INFLUENCE OF COATINGS AND SURFACE IMPROVEMENTS ON THE LIFETIME OF GEARS

Franz Joachim, Norbert Kurz and Bernhard Glatthaar

Abstract

Surface coatings or finishing processes are the future technologies for improving the load carrying capacity of case hardened gears. With the help of basic tests, the influence of different coatings and finishing processes on efficiency and resistance to wear, scuffing, micropitting, and macropitting is examined.

Reports on experience with coated gears in different transmissions are depicted. In the past, coated transmission gears have been used to repair inadequate gear designs. Future application of such technologies will depend on verified test data and will be selected only if the technologies are reliable and cost-effective.

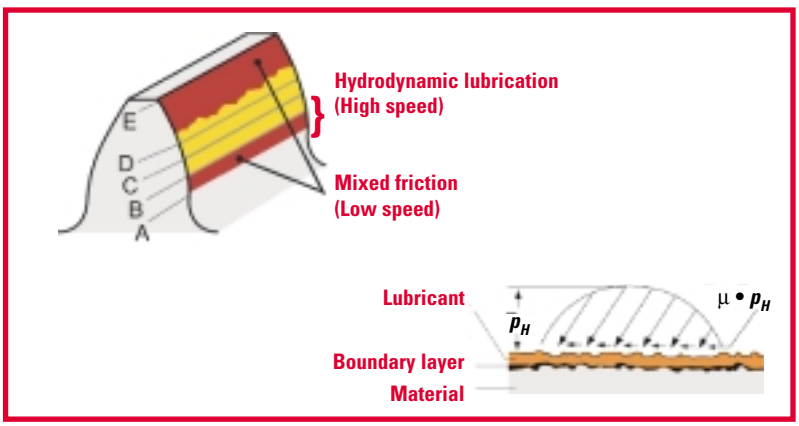


Figure 1—Gear flank lubrication model.

Introduction

The development of vehicle transmissions is characterized by continuously increasing levels of torque and power, lightweight designs, increased service lives, improved efficiency and more stringent noise requirements. Over the last few years, the opportunities provided by conventional technologies to increase performance have all been fully exploited. Future technologies for increasing gear flank load capacity are surface coatings or finishing processes. These possibilities, however, are just starting to be developed and are still insufficiently investigated. To evaluate their potential for optimization in terms of gear load capacity and efficiency, a number of fundamental investigations have been conducted within ZF (Refs. 1–3). Test results obtained with physical vapor deposition (PVD) hard coatings and a superfinishing procedure are reported below, such as superfinishing and honing.

Tribological System

The lubrication status of two meshing gear flanks is characterized by limit/mixed friction and hydrodynamic lubrication (see Fig. 1). This is greatly influenced by the operating conditions, lubricant, gear geometry and surface characteris-

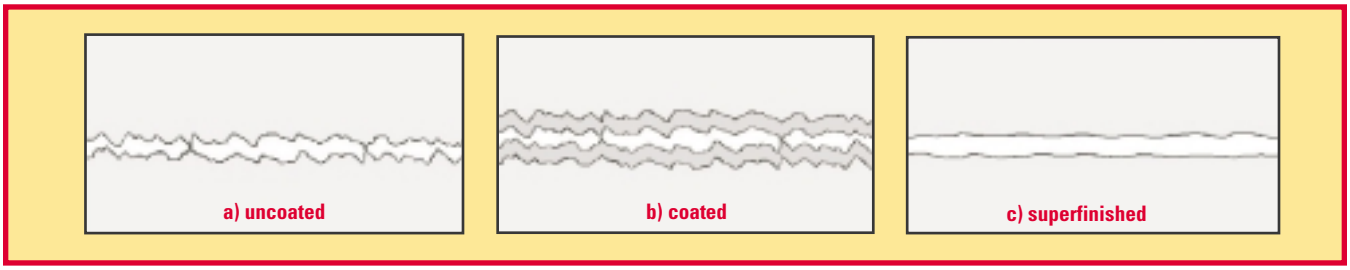


Figure 2—Characteristic surface treatments.

tics. At low pitch-line velocity, limit and mixed friction occur; and at higher pitch-line velocity, an elasto-hydrodynamic (EHL) film of lubricant may form.

Figure 2 shows comparisons of the geometry of contact zones (in diagrammatic form) for the following surfaces: uncoated, coated and superfinished. The coated surface shown here is a coating true to both the contour and surface. Solid body friction occurs on some of the peaks in roughness on both "rough" uncoated and coated surfaces. However, the coating represents a specifically applied layer of surface protection to obtain favourable friction and run-in characteristics. The superfinished surfaces are separated by an EHL film, and friction is dominated by shearing of the lubricant film.

In all three instances, the effect of the surface response layer is most significant. The form of this layer depends on the lubricant, condition of the surface, and chemical reactions. It can also affect the friction characteristics.

The effect of friction on Hertzian stresses is shown in Figure 3. This shows that with increasing friction, the maximum subsurface stress moves closer to the surface and therefore encourages the emergence of surface fatigue damage, such as micropitting and macropitting.

Surface Treatment Procedure

As mentioned above, gear flank load-bearing capacity is determined by a number of factors. In addition to material, heat treatment, gear geometry corrections and lubricant, these include surface treatment procedures such as coating and finishing processes. The causal relationships between gear flank load-bearing capacity, coatings and finishing processes are illustrated in Table 1. In the past, gear coatings primarily took the form of soft layers used to improve running-in characteristics and scuffing resistance. In the first instance, this involved phosphating and copper plating. For final finishing of gears and splines, various types of grinding, honing and superfinishing can be employed.

The investigation results itemized in the following section focus primarily on PVD coating and chemically accelerated superfinishing.

Coatings. The main focus will be on tungsten carbon carbide (WC/C) and amorphous boron carbide (B4C) (Refs. 4–5).

The tungsten carbon carbide layer WC/C is a metallic-hydrocarbon layer (Me-C:H), which is increasingly used in automotive construction and mechanical engineering to reduce wear. These layers are applied using a PVD process which permits coating and material temperatures less than 200°C and therefore makes the coating of case hardened components possible. The layer is characterized by high levels of hardening, a low friction coefficient and high elasticity. The characteristics of WC/C are shown in Table 2.

The typical layer structure is shown in Figure

Gear failures usually start at the surface or in the outer layer.
- adhesive wear
- scuffing
- micropitting
- macropitting

Table 1—Methods to Increase Gear Flank Durability.

Influence	Coatings	Superfinishing
reduced coefficient of friction	X	X
running-in effect	X	(X)
boundary layer, separation, strength	X	(X)
corrosion protection	X	

* Without Parentheses: Perfectly applicable; With Parentheses: Only partially applicable

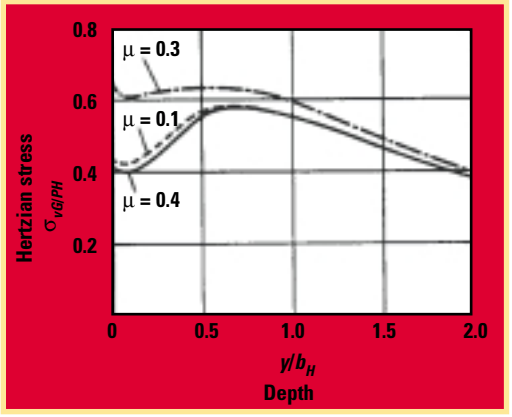


Figure 3—Influence of friction on Hertzian stress.

Table 2—Characteristics of WC/C and B4C.

Coating	WC/C	B4C
Coating material	tungsten, carbon	boron, carbon
Coating design	lamellar	amorphous
Coating temperature	150–250°C	≈120°C
Coating thickness	1–4 µm	≈ 2 µm
Hardness	800–1,600 HV	> 3,000 HV
Elastic modulus	0.8–1.6 • 10^5 N/mm^2	
coefficient of friction	coating against steel: dry	0.25
	coating against steel: mixed friction/drop lubrication	0.04
	steel against steel (uncoated): dry	> 0.60
	steel against steel (uncoated): mixed friction/drop lubrication	0.15
	steel against steel (uncoated): EHL lubrication	0.05

Dr.-Ing. Franz Joachim
is senior manager–gear development in corporate research & development at ZF Friedrichshafen AG, located in Friedrichshafen, Germany. A mechanical engineer, he supervises gear design and development.

Dr.-Ing. Norbert Kurz
is manager of the gear laboratory in corporate research & development at ZF Friedrichshafen. As manager, he's responsible for the laboratory's performing of basic gear tests, including gear load capacity and gear noise.

Dipl.-Ing. Bernhard Glatthaar
works in the gear laboratory in corporate research & development at ZF Friedrichshafen, performing basic tests of gears.

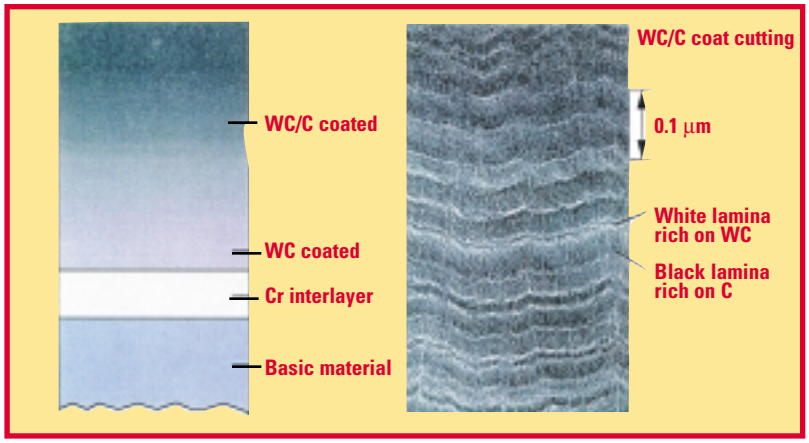


Figure 4—WC/C layer structure, according to Balzers.

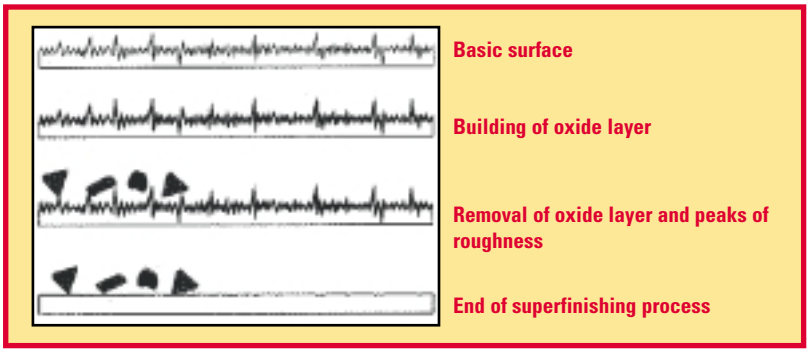


Figure 5—Principle of chemically accelerated superfinishing (Ref. 6).

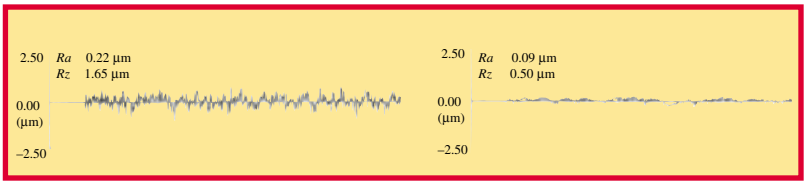


Figure 6—Roughness before and after superfinishing (FZG-C-gear).

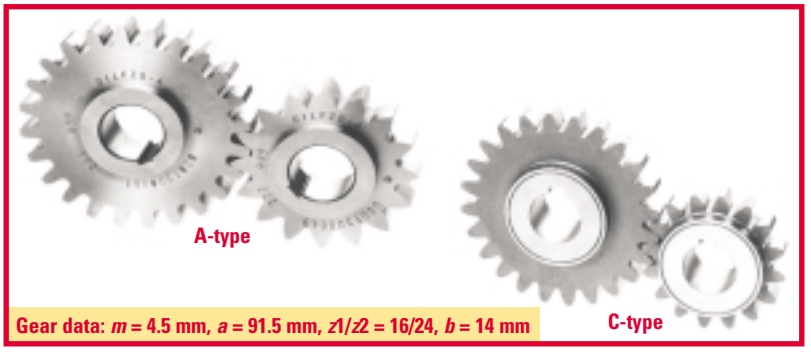


Figure 7—FZG test gears.

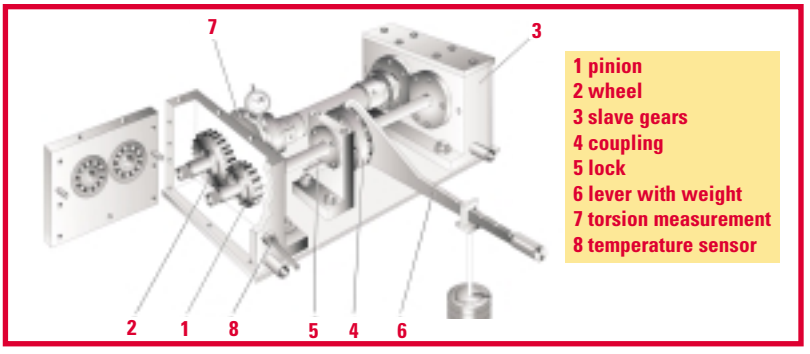


Figure 8—FZG gear tester—test equipment for basic gear tests.

4. This is a lamellar layer structure in which carbide and carbon-rich phases alternate at intervals of a few atoms. This produces good antifriction characteristics. The layer is true to the contour and does not notably modify the surface roughness.

B4C is applied using a PVD process similar to that used for WC/C. This layer has a substantially higher hardness level than WC/C.

The properties of both layers are defined in Table 2.

Chemically accelerated superfinishing. Standard superfinishing uses grinding particles to abrasively remove peaks of roughness, whereas chemically accelerated superfinishing uses a fluid compound (Ref. 6). This creates an oxide layer on the workpieces, which the grinding bodies continuously remove from the surface together with the peaks of roughness. For the principle behind the procedure, refer to Figure 5. Once the required surface quality has been reached, the oxide layer is removed using a second fluid compound. The reduction in roughness depends on the initial roughness and period of superfinishing. Examples of roughness measurement plots of ground gear flanks before and after superfinishing are shown in Figure 6.

Fundamental Investigations

Gears, test rig, test procedure. Type FZG-A and FZG-C gears were used for the comparative tests (see Fig. 7). The FZG-A gear is a standard test gear (DIN 51354) used for scuffing tests. The gear is designed especially for high sliding speeds and therefore responds with particular sensitivity to scuffing damage. The FZG-C gear is standardized and is used for macropitting, wear, and micropitting tests. The gear geometry has balanced specific sliding. Both gear types have no modifications (crowning, tip relief) and are produced by ZF according to specifications.

The widely used FZG gear test rig is employed when conducting gear tests (see Fig. 8).

Various gear test procedures were used to investigate the load capacity and efficiency. These will only be described briefly here. The most important test parameters are listed in Table 3.

During the FZG test to investigate scuffing load capacity, the loading and pressure are gradually increased at intervals of 15 minutes (load stages 1–12) until scuffing occurs.

The FZG macropitting test is used to evaluate the macropitting load capacity. The transmission is operated under constant operating conditions until macropitting occurs (maximum up to 300 hrs or 40 x 10^6 load cycles). Low speed wear

characteristics are evaluated in the ZF wear test. Constant operating conditions are maintained over specific runtime intervals and the gear's loss in weight determined.

The ZF efficiency test is used to determine the gear's power loss and the gear friction coefficient. The input torque induced in the test rig is measured under different test conditions.

Scuffing load capacity. Scuffing load capacity is also affected by the characteristics of the flank surface in addition to the operating conditions, gear geometry, lubricant and material. All measures resulting in a lower flank temperature (reduction in friction) favor high scuffing load capacity. This also applies to the two hard layers investigated and the superfinishing, as is shown in Figure 9.

This produces a clear increase in scuffing load capacity for the WC/C and B4C layers. An improvement of approximately two damage load stages corresponds to an increase in torque capacity of approximately 50%.

In this instance, the change in oil temperature over the individual load stages is also evaluated. Figure 10 shows the oil temperature established in each instance towards the end of the runtime of a load stage (output temperature before start of a load cycle is always 90°C).

It can be noted that a lower oil temperature occurs with both the coated and superfinished gears than on the uncoated gears. This is due to the improved friction characteristics. The fact that superfinished gears, with very favorable temperature characteristics, fare less well than those with WC/C or B4C in terms of scuffing resistance, must be due to the fact that the coating material itself (regardless of the formation of a film of lubricant) is less prone to scuffing than the base material.

Macropitting load capacity, formation of micropitting. In the FZG macropitting test, a clear increase in load capacity was found for coated gears when compared with uncoated gears, Figure 11, but only if both gears are coated. This resulted in increases in lifetime by a factor of 2–3.

The poor relative performance of the superfinished gears has not yet been clarified. Despite better friction characteristics, no improvement is gained from superfinishing when compared with the "rough" initial condition. There could be many reasons for this. Since the test gears have no profile modifications, very high levels of pressure arise at the start of meshing. Regardless of the surface condition, this will only permit boundary

Table 3—Gear Test Procedures.

Test designation	Gear type	Pitch-line velocity (m/s)	Temperature (°C)	Pressure σ_{H0} (N/mm²)	Test procedure
FZG scuffing test	A	8.3	90 (Start temp.)	135–1,730	15 min/Load Stage (LS); (max. 12 LS)
FZG macropitting test	C	8.3	90	1,530	max. 300 hrs
ZF wear test	C	0.03	80	2,035	20+40+40 hrs
ZF efficiency test	C	8.3	20/.../100	1,190	about 20 min/ Temperature stage

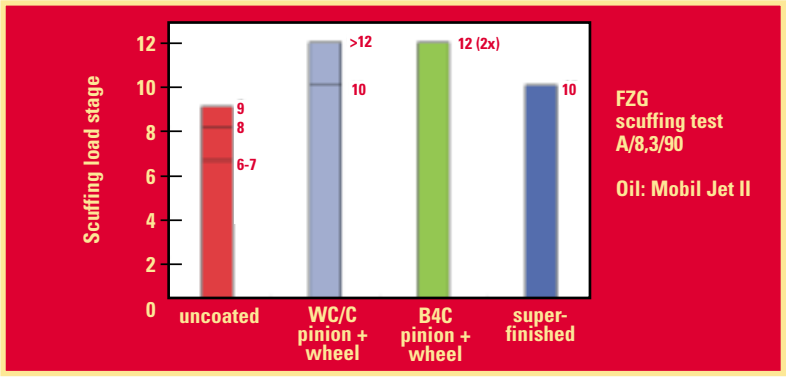


Figure 9—Scuffing resistance.

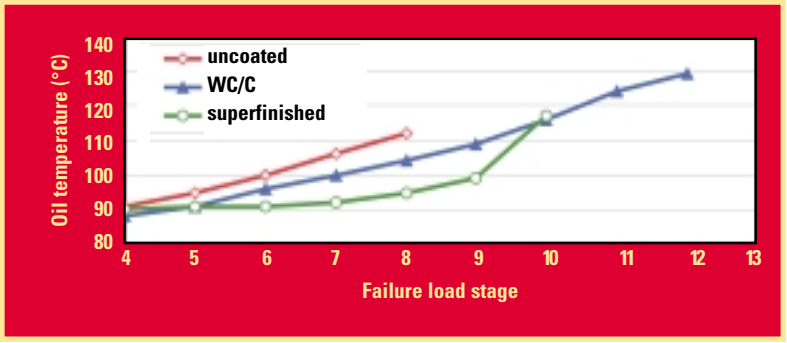


Figure 10—Temperature in the FZG scuffing test.

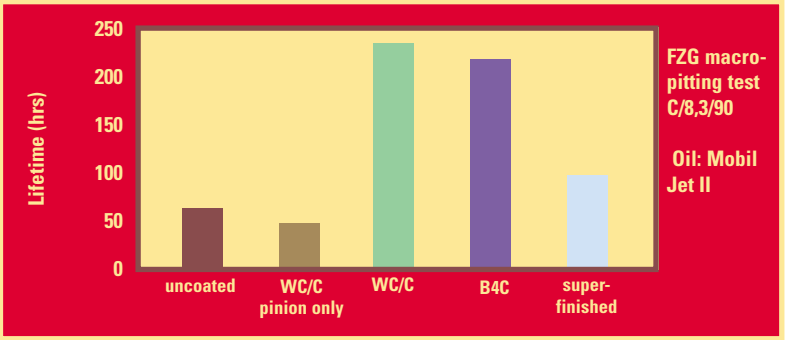


Figure 11—Macropitting test results.

Figure 12—Macropitting failure.

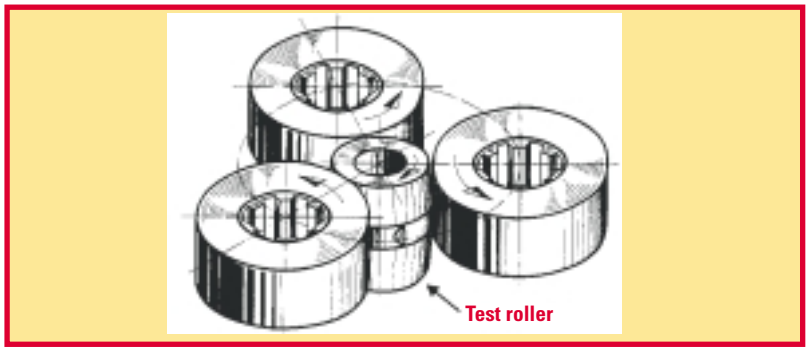


Figure 13—Principle of ZF roller test rig.

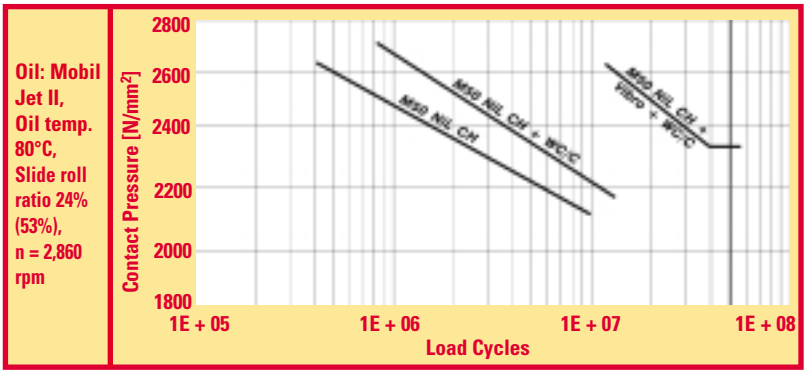


Figure 14—ZF roller tests with WC/C-coated rollers.

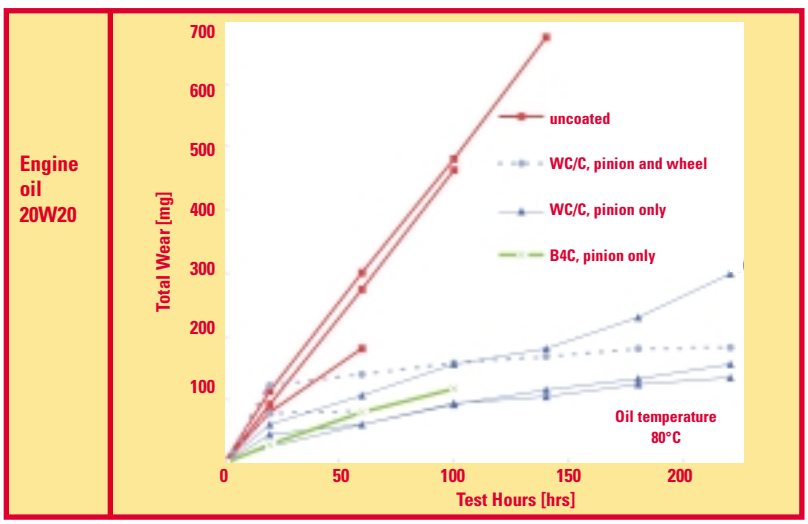


Figure 15—Results of the slow speed wear test.

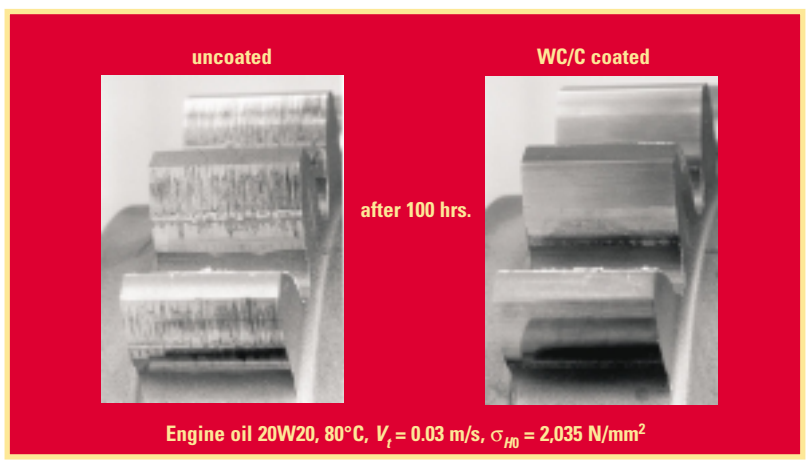


Figure 16—Gear flank surfaces after slow-speed wear test.

lubrication, and the friction characteristics are therefore mainly the same in both untreated and superfinished conditions. Another possible cause may be metallographic surface changes during superfinishing, caused by chemical action which takes place during the superfinishing machining (formation of oxide layer). However, this has not been proven, and more detailed investigations are still required on this matter.

The macropitting damage pattern is the same for all gears investigated. Figure 12 shows an example of a comparison of an uncoated gear and a WC/C-coated gear. As usual, macropitting occurs in the area of negative slip, with WC/C only after approximately 2–3 times the other run time. With the WC/C gear, machining/grinding marks can still be seen after this relatively long run time. Most of this will have already been removed after approximately 30% of the run time on the uncoated gears.

Investigations to compare the macropitting load capacity were also conducted as part of the research project ASETT (The Development of Advanced Surface Engineering Techniques for Future Aerospace Transmissions) sponsored by the European Commission (Ref. 3). The case hardened aviation steel M50NiL (AMS 6278) was tested in what are commonly referred to as ZF roller tests (see Fig. 13). An increase in load capacity (by a factor of 2–3) was obtained with the WC/C coating when compared with that of the uncoated initial condition (see Fig. 14). When the coating process is preceded by superfinishing, a further substantial increase in service life was achieved. The combination of superfinishing and a hard material layer (CH+Vibro+WC/C) achieved an increase in service life in untreated condition equivalent to a factor of 10–15.

Wear. Wear occurs mainly when the slide partners are incompletely separated at low circumferential speeds (< 0.5 m/s), where only an insufficient film of lubricant is able to form. Possible remedial measures in this instance could be: to increase the surface hardness, to reduce the surface roughness or to optimize the lubricant (increased viscosity, suitable additives).

Low-speed wear tests were conducted to investigate the extent to which the wear characteristics of gears are influenced by a hard material layer.

Figure 15 shows the positive influence of WC/C and B4C on wear resistance, whereby the material removal resulting over the test run time

is noted in milligrams (in total for both pinion and gear). The removal for the coated gears is approximately 5 times less than that for the uncoated gears. It is interesting to note that, in this instance, simply coating one slide partner is sufficient and coating both partners did not result in any further improvement.

Figure 16 shows the gear flank surfaces after 100 hours of operation in the low-speed wear test. The uncoated gear stands out here because of the severe abrasive wear grooves running in parallel with the gear height. The coated gears, on the other hand, did not display any abrasive wear, and the flanks have no signs of damage.

Efficiency. The efficiency of a transmission is primarily determined by friction losses in gear meshing. This is mainly dependent on gear geometry, operating conditions, lubricant, and surface quality (roughness) of the gear flanks.

The potential for reducing friction or improving efficiency, which can be gained by coating or superfinishing gears, is shown in Figures 17 and 18. The gear friction coefficient determined using the gear efficiency test is noted here as a characteristic reference number which is proportional to the loss of gear power.

Both the WC/C layer and the superfinishing give reductions in friction of up to 30%. These improvements are comparable to those obtained with "untreated" flank surfaces when changing from mineral-based oil to synthetic oil. Significant improvements can also be gained with the WC/C layer itself when using synthetic oil (see Fig. 18).

Transmission Applications/ Real-Life Examples

Based on the results from fundamental investigations, application investigations were also conducted on transmissions. This involved particularly critical applications where, for example, slow-speed wear occurred or, in isolated cases, where enhanced performance was required.

Table 4 illustrates coatings for different transmissions, problem definitions and applications.

Very positive results were obtained when tackling problems involving slow-speed wear. For example, with a concrete mixer transmission, shown in Figure 19, wear was almost completely eliminated on a slow-running and wear-prone planetary gear stage. This elimination was achieved by coating only the sun gear. In contrast to this, it did not prove possible to solve the problems of fretting corrosion in a commercial vehicle transmission by applying a hard material coating.

In the case of macropitting-related damage patterns, only slight improvements were achieved. In some cases, problems with coating adhesion (bonding) were encountered. Possible causes for this might have been high levels of local contact pressure, which might have culminated in failure (tearing away) of the coating layer.

Positive results were achieved when tackling a problem of micropitting in a power-splitting tractor transmission. Noise problems were encountered in a planetary stage. These were caused by severe cratering on the sun gear, resulting from micropitting (see Fig. 20). Given that micropitting is influenced to a major extent by surface roughness, the first step taken to solve the problem was honing, but this approach only met with limited success. The problem of micro-

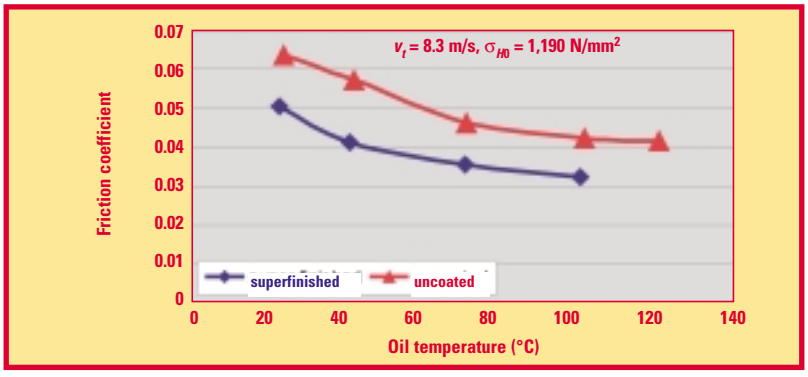


Figure 17—Measured coefficient of friction for mineral oil.

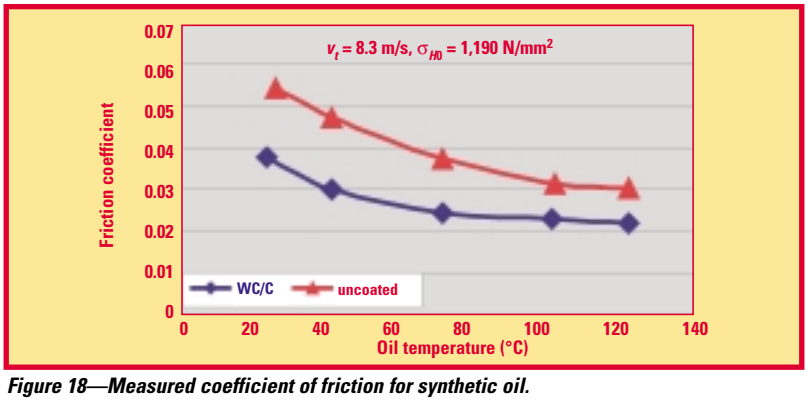


Figure 18—Measured coefficient of friction for synthetic oil.

Table 4—Experience with Coated Gears in Transmissions.

Application/Transmission	Problem	Coated Parts	Result
Concrete mixer	Wear	Sun gear	+
Automatic bus transmission (race truck)	Macropitting	Sun gear	+
Flap actuator	Wear	Internal gear	+
Truck transmission (planetary gear set)	Fretting corrosion	Sun gear	–
Automatic car transmission	Macropitting	Sun & planet gears	–
Manual car transmission	Macropitting	Pinion shaft	–
Tractor transmission	Micropitting	Pinion	+

pitting was not resolved until a coating was applied.

In overall terms, it has been established that coating offers great potential for optimizing components. Having said that, this is highly dependent on the application in question and on the influencing parameters, not all of which are fully understood at this time. There is therefore no option to performing a separate test for each application.

It is also still uncertain how layers behave in response to interactions between the lubricant and its additives. Here the question of mutual impact of lubricant and coating arises. For example, there are lubricants where certain types of coatings do not work. Why is that so?

The failure of boundary layer formation processes to occur may have a key role to play in this.

Lubricants usually react when in contact with a friction partner's surfaces and there, they are creating boundary layers (barrier layers). So the question arises whether these boundary layers are also created when the surfaces are coated?

Going a step further, are these boundary layers still required in case of coatings? Or even worse, may they have a detrimental impact?

Tests were not run for this interference, though, so this discussion is speculative.

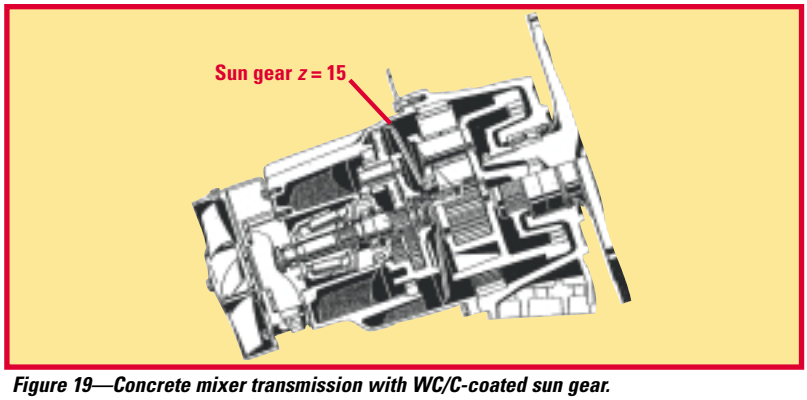


Figure 19—Concrete mixer transmission with WC/C-coated sun gear.

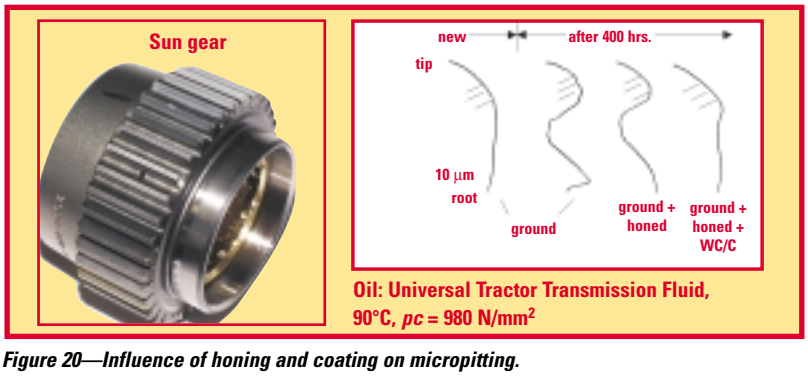


Figure 20—Influence of honing and coating on micropitting.

Conclusion

PVD coating and superfinishing can sometimes provide significant increases in scuffing resistance, wear resistance, macropitting resistance, and micropitting resistance. Furthermore, the coefficient of friction can be reduced. However, results of transmission tests with different transmissions and applications vary. The reasons are not clearly understood. Maybe coatings and surface improvements are sensitive to edge loading, inadequate tip relief, the wrong type of lubricant, or other factors. So far, surface improvements have mostly been used as problem solvers. In the future, they will become construction elements of surface engineering. Further influences and properties have to be investigated, such as endurance limits, surface roughness, structure, pre-treatment, influence of lubricant, coefficient of friction, efficiency, adherence, and quality control. ⚙

This paper was presented at the International Conference on Gears, held March 13–15, 2002, in Munich, Gemany. It has been twice published by VDI. The first publication was in VDI report 1665, the conference's proceedings, via VDI Verlag GmbH. The second publication was in the March 2004 issue of* Konstruktion *magazine, which is published through Springer VDI Verlag. The paper is republished here with VDI's permission.

References

1. Joachim, F. J. "Influence of Coatings on the Durability of Case-Hardened Gears," 2nd Balzers Technical Forum, Bingen, Germany, Oct. 16–17, 2000.

2. Glatthaar, B., F. J. Joachim and N. Kurz. "Langsamlaufverschleiß in Leistungsgetrieben," *Tribology 2000-Plus*, *Technische Akademie Esslingen*, 12th International Colloquium, Esslingen, Germany, Jan. 11–13, 2000, pp. 585–591.

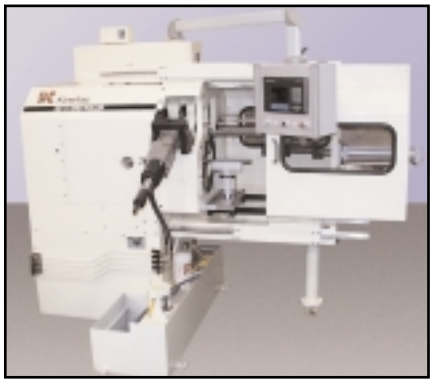
3. Kleff, J. and D. Wiedmann. "Neue Wege bei der Wärmebehandlung und Oberflächenbehandlung hochbelasteter Luftfahrt-Getriebebauteile," *Härterei-Technische Mitteilungen*, Vol. 55, No. 1, 2000, Carl Hanser Verlag, München, Germany, pp. 59–64.

4. Michler, Th. and M. Laakmann. "Verbesserung der tribotechnischen Eigenschaften von Verzahnungen durch WC/C-Schichten," *Antriebstechnik*, Vol. 99, No. 6, 1999, pp. 67–70.

5. Stott, W. "Myths and Miracles of Gear Coatings," *Gear Technology*, Vol. 16, No. 4, July/Aug. 1999, pp. 35–44.

6. Michaud, M., G. Sroka, and L. Winkelmann. "Chemically Accelerated Vibratory Finishing for the Elimination of Wear and Pitting of Alloy Steel Gears," *News Digest*, Vol. 60, No. 1, Winter 2003, pp. 21–37.

Latest Gear Industry Products



New Spline Rolling System from Kinefac

The MC-6 FTF Kine-Roller from Kinefac is a spline rolling system that provides CNC control and programming for size, rolling feed rate, die speed and part feed rate.

According to the company's press release, the three cylindrical dies can be matched by using their direct-die phasing system and torque sharing die drive.

The roller can produce tooth-to-tooth spacing error below 25 microns and pitch diameter within 40 microns on splines up to 50 mm in diameter with pressure angles from 30–45°. In addition, the use of this system with its roll generating design provides maximum stability for the forced feed-thru spline rolling process.

For more information, contact Kinefac at (508) 754-6891 or by e-mail at *sales@kinefac.com.*

NEW BROCHURE FROM LOGANSPORT

A new 12-page electronic brochure from Logansport Matsumoto Co. features its line of workholding chucks, suitable for automotive part machining and high volume applications.

The products represented include the PS and PG power swing chucks from 6–12" angled work, PB pin arbor chucks from 5–10", and the PBH and PBN pin arbor chucks.

NEW AXIS KEYWAY CUTTER FROM COMMAND TOOLING

Cutting a keyway is one of the most common operations in gear manufacturing. Usually, keyways are cut using a broaching process, but engineers at Command Tooling Systems thought there had to be a faster and cheaper way to go about it.

The New Axis Keyway Cutter from Command Tooling Systems, a toolholding company located in Ramsey, MN, is the latest extension of the traditional right angle head. This version fits right in a milling machine, eliminating any secondary operations and saving setup time, says Bob Saby, the company's product manager.

The cutter is hydraulically powered, driven by a machining center's coolant system. It can machine keyways, splines or grooves without spindle rotation, in bores down to 1/2" diameter. The spindle rotation is not required for power because the positive displacement ball piston motor in the head achieves speed and torque relative to coolant flow and pressure.

Command Tooling Systems considers itself to be the only company to use fluid-driven means for key cutting.

According to Saby, Command Tooling has sold 45 units so far. Available in BT 40, CT 40, CT 50, HSK63A and straight shank sizes, the cutter can also produce odd-size keyways via multiple passes to meet depth and width requirements.

These keyway cutters use the same couplings as the company's larger, fluid-driven right angle head.The New Axis Right Angle, Fluid-Driven Cutter Head features an elliptical design head for machining cavities within 1" diameter.

Heads clamp the machining spindle and, like the keyway cutter, it doesn't require spindle rotation. Since it is free to function as an indexer, the C-axis allows machining at multiple radial positions with a single setup.

Loading is done from an automatic tool changer and, aside from keyway cutting, the heads are suitable for milling oil grooves, drilling bleeder holes at right angles to piston bores and machining at multiple radial positions on monolithic parts.

For gear companies, the most likely applications are automotive. However, the New Axis may not be a solution for all gear manufacturers since the system requires 300 lbs. of coolant pressure.

"Most newer machines have high pressure coolant, but we have run into companies without it," says Saby.

Nonetheless, he counters that this keyway cutter is still a cost-saver for the majority of companies. "It's universal, can cut small bore sizes and is definitely more compact than mechanically driven heads," he says.

Other items featured are the System 2R Hydraulic Rotating Cylinders for high performance chucking applications as well as other power-operated chucks, rotating cylinders and wheel chucks/actuators, multi-axis rotary tables for turning and EDM applications.

For more information, contact Logansport Matsumoto Co. of Logansport, IN, by telephone at (574) 735-0225 or on the Internet at *www.logan-mmk.com*.

NEW TORQUE SENSOR FROM SENSOR TECHNOLOGY

The RWT310/320 series of Torqsense rotary torque sensors from Sensor Technology is designed for plug-and-play fitting.

According to the company's press release, it does not need physical contact with the shaft it is monitoring. This is because it uses a radio frequency coupling to power and read the output of a small piezoelectric comb mounted on the shaft's surface and acting as a hypersensitive strain gauge.

During rotation, all the shafts twist at a microscopic level, and this deforms the comb so that its fundamental frequency changes. The twist and frequency change are related to the torque in the shaft, so monitoring the comb gives a direct torque measurement.

The sensor comes with integral electronics, outputs for torque, speed, power and angle, analog and/or digital outputs, a built-in peak torque sampling, storage and torque averaging, and a self-diagnostic test package.

For more information, contact Sensor Technology of Oxon, U.K., on the Internet at *www.sensors.co.uk*.

Tell Us What You Think . . .
Send e-mail to *wrs@geartechnology.com* to
• Rate this column
• Make a suggestion
Or call (847) 437-6604 to talk to one of our editors!

LECOUNT RECEIVES EXPORTER AWARD

LeCount Inc. was named Exporter of the Year by the Vermont International Business Council (VIBC), a standing committee of the Vermont Chamber of Commerce.

According to the Chamber of Commerce press release, this award recognizes LeCount's contribution to Vermont's international trade stature through international distributorships, private label distributorship agreements and partnerships with large manufacturers.

LeCount, located in White River Junction, VT, manufactures expanding mandrels and hydraulic workholding tooling for gear manufacturers worldwide.

IMS GEAR AND JOS. KOEPFER EXPAND CUTTING TOOL DIVISIONS

Ims.koepfer.cuttingtools.gmbh, a new cutting tools company created from the combined divisions of IMS Gear of Eisenbach, Germany and Jos. Koepfer of Furtwangen, Germany, began operations on June 1.

The new company will have an expanded range of cutting tools and will be marketed throughout Europe and North America, according to the company's press release.

Among the products they will manufacture are both high speed steel and carbide hobs in bore and shank designs.

A maximum diameter of 180 mm (7.087") and a total length of 400 mm (15.748") is available.

ROMAX TECHNOLOGY RECEIVES AWARD

Romax Technology, a transmission-engineering specialist based in Nottinghamshire, U.K., was a recipient of the Queen's Award for Enterprise in International Trade.

According to the company's press release, this award recognizes Romax's first time annual sales figures of more than £2 million.

Romax, with customers in the U.S., Germany, France, Japan, Korea and India, designs, analyzes, tests and specifies gearboxes and software.

ABSOLUTE MACHINE TOOLS ADDS NEW PRODUCT LINE

Absolute Machine Tools has entered into an exclusive marketing agreement

INDUSTRY NEWS

with Lih Chang Machinery Co. Ltd. of Taiwan to carry its Argo Seiki line of CNC machine tool products in the United States.

The Argo Seiki line consists of high speed drilling and tapping centers as well as several high speed vertical machining centers for production machining.

All Argo Seiki units are manufactured under ISO 9001 standards and will be displayed at the Absolute Machine Tools booth at IMTS.

NEW PRESIDENT AT SUMITOMO MACHINERY


Ronald J. Smith

Ronald J. Smith was promoted to president and COO of Sumitomo Machinery Corp. of America.

He has been with the company for the past 12 years, most recently as vice president of sales and marketing. Prior to joining SMA, he had worked in the power transmission industry for more than 25 years.

AFC-HOLCROFT OPENS SHANGHAI OPERATION

AFC-Holcroft LLC of Wixom, MI, and Shanghai Powermax Furnace Corp. of Shanghai, China, have signed a cooperative agreement.

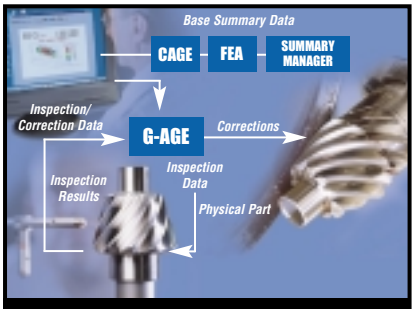
Both companies will market, manufacture and service heat treat equipment by using AFC-Holcroft technology.

According to the company's press release, this agreement will allow AFC-Holcroft to utilize Shanghai Powermax Furnace Corp.'s manufacturing area, furnace engineers and technicians.

Tell Us What You Think . . .
Send e-mail to *wrs@geartechnology.com* to
• Rate this column
• Make a suggestion
Or call (847) 437-6604 to talk to one of our editors!

CLASSIFIEDS

SOFTWARE



CLOSE THE LOOP ON QUALITY

GEMS™ Expert Manufacturing System

Gleason combines a collection of software with Gleason cutting, grinding and inspection equipment to produce bevel gears faster and more accurately every time.

www.gleason.com

HEAT TREATING

Induction Hardening

Specialists in Tooth by Tooth Contour Hardening of Internal *Spur, helical and bevel gears*

Our gear hardening equipment includes 5 NATCO submerged process machines and 5 AJAX CNC-controlled gear scanning machines. Tooth by tooth gear hardening from .5DP-10DP, up to 15 tons, 200" diameter.

American Metal Treating Company
Cleveland, Ohio
Phone: (216) 431-4492 • Fax: (216) 431-1508
Web: *www.americanmetaltreating.com*
E-mail: *bruce@americanmetaltreating.com*

Breakdown Service Available

HELP WANTED

SERVICE ENGINEER

Reishauer is the world's leading supplier of Gear Hard Finishing equipment.

We are currently seeking an engineer to service CNC Thread and Gear grinding equipment.

This position requires travel throughout the United States and Canada.

We offer full benefits, including medical, dental and 401K plan.

Mail or fax resume to:
Reishauer Corporation
1525 Holmes Road
Elgin, IL 60123
Fax 847-888-0343
reishauer@reishauer-us.com

SERVICE

- CONTRACT METROLOGY SERVICES
- CURVIC COUPLING GRINDING & INSPECTION
- BEVEL & CYLINDRICAL DEVELOPMENTS & PROTOTYPES
- APPLICATION ENGINEERING SUPPORT & DESIGN SERVICES
- HEAT TREATMENT
- REPLACEMENT HELICAL GUIDES FOR SHAPERS, INCLUDING FELLOWS

SPECIALIZED GEAR SERVICES

The Gleason Works
1000 University Ave., P.O. Box 22970
Rochester, NY 14692-2970 U.S.A.
Phone: 585/473-1000
Fax: 585/461-4348
E-mail: sales@gleason.com

www.gleason.com

- BROACH SHARPENING
- HOB SHARPENING
- SHAVING CUTTER GRINDING
- THIN FILM COATING
- CUSTOM HEAT TREAT SERVICE
- REPLACEMENT HELICAL GUIDES FOR SHAPERS, INCLUDING FELLOWS

PICK UP AND DELIVERY IN MANY AREAS

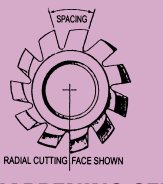
Gleason Cutting Tools
CORPORATION
1351 Windsor Road
Loves Park, IL 61111 U.S.A.
Phone: 815/877-8900
Fax: 815/877-0264
E-mail: gctc@gleason.com

www.gleason.com

HOB SHARPENING
(763) 425-5247

★ ***THIN FILM COATINGS*** ★

HSS & Carbide up to 5" Dia.
Straight Gash,
Sharpened & Inspected
Per AGMA STANDARDS
Quick Turnaround



KORO SHARPENING SERVICE
9530 - 85TH AVENUE NO.
MAPLE GROVE, MN 55369
info@koroind.com

Rates—Line Classified: 1" minimum, $325. Additional lines $45 per line (8 lines per inch). Display Classified: 3" minimum: **1X**—$735, **3X**—$685 per insertion, **6X**—$645 per insertion. Additional per inch: **1X**—$255, **3X**—$235 per insertion, **6X**—$225 per insertion. **Color Classified:** Add $150 per insertion for color. *Gear Technology* will set type to advertiser's layout or design a classified ad at no extra charge. **Payment:** Full payment must accompany classified ads. Send check drawn in U.S. funds on a U.S. bank or Visa/MasterCard number and expiration date to *Gear Technology*, P.O. Box 1426, Elk Grove Village, IL 60009. **Agency Commission**: No agency commission on classified ads. **Materials Deadline:** Ads must be received by the 15th of the month, two months prior to publication. **Acceptance:** Publisher reserves the right to accept or reject advertisements at his discretion.

SERVICE

GEAR MANUFACTURING

WEBSITES

GEAR MOTIONS, INC.

Learn about one of the most modern fleets of Gear Grinders, including the new Höfler 700 at Oliver Gear. See the latest Reishauer Gear Grinding technology, at ISO 9001-2000 registered Nixon Gear, as well as the latest in CNC Gear Hobbing and cellular manufacturing.

www.gearmotions.com

GLEASON CORPORATION

Gleason is the world's most comprehensive resource for gear manufacturing technology. We offer a comprehensive gear cutting machine program for every gear hobbing, milling and grinding application for cylindrical and bevel gears. To learn more about our products and services or to find key contact information, see our Web site.

www.gleason.com

GLEASON CUTTING TOOLS CORPORATION

Gleason Cutting Tools Corporation is the leading gear cutting tool manufacturer in North America. We offer a wide variety of form-relieving milling cutters, hobs, shaper cutters, shaving cutters and CBN-plated form grinding wheels as well as our engineering, coating, heat treating, metallurgical, tool sharpening and reconditioning services.

www.gleason.com

ADVERTISER INDEX

USE RAPID READER RESPONSE to contact any advertiser in this issue *www.geartechnology.com/rrr.htm*
Rapid Reader Response: It's FAST! It's EASY! It's ONLY ONLINE!

Advertiser	Page	Phone	E-mail	Internet
Allen Adams Shaper Services Inc.	62	(802) 259-2937	adams@vermontel.net	
American Metal Treating Co.	61	(216) 431-4492	bruce@americanmetaltreating.com	www.americanmetaltreating.com
Arrow Gear Co.	4, 60	(630) 969-7640	bevels@arrowgear.com	www.arrowgear.com
Atlas Gear Co.	62	(248) 583-3000	bob@atlasg.com	www.atlasgear.com
A/W Systems Co.	25, 28	(248) 544-3852		
Barit International Corp.	4	(847) 272-8128	people@barit.com	www.barit.com
Bently Pressurized Bearing Co.	39	(775) 783-4600	sales@bpb-co.com	www.bpb-co.com
Bourn & Koch Inc.	BOC	(815) 965-4013	bournkoch@worldnet.att.net	www.bourn-koch.com
Clifford Jacobs Forging	38	(217) 352-5172	sales@clifford-jacobs.com	www.clifford-jacobs.com
Colonial Tool Group Inc.	49	(734) 946-2733		www.colonialtool.com
Comtorgage Corp.	12	(401) 765-0900		www.comtorgage.com
De.Ci.Ma SpA	39	(39) (051) 611-7811	info@decimaspa.it	www.decimaspa.it
Euro-Tech Corp.	31	(262) 781-6777	info@eurotechcorp.com	www.eurotechcorp.com
Gear Motions Inc.	63	(315) 488-0100	ronwri@nixongear.com	www.gearmotions.com
The Gear Works—Seattle, Inc.	62	(206) 762-3333	sales@thegearworks.com	www.thegearworks.com
Gleason Corp.	IFC–1, 24, 28, 61, 63	(585) 473-1000	dmelton@gleason.com	www.gleason.com
Gleason Cutting Tools Corp.	28, 61, 63	(815) 877-8900	dmelton@gleason.com	www.gleason.com
IMTS 2004	48	(800) 322-4687	amt@mfgtech.org	www.imtsnet.org
Inductoheat Inc.	11, 31	(248) 585-9393	sales@inductoheat.com	www.inductoheat.com
Insco Corp.	38	(978) 448-6368	sales@inscocorp.com	www.inscocorp.com
Interstate Tool Corp.	62	(216) 671-1077		www.interstatetoolcor.com
ITW Heartland	20	(320) 762-8782	itwgears@rea-alp.com	www.itwgears.com
JRM International Inc.	13	(815) 282-9330	jrmsales@jrminternational.com	www.jrminternational.com
Kapp Technologies	3, 27, 31	(303) 447-1130	info@kapp-usa.com	www.kapp-usa.com
KISSsoft AG	21	(41) (55) 264-2030	info@kisssoft.ch	www.kisssoft.ch
Klingelnberg AG	18	(734) 429-7225	info@lgt.liebherr.com	www.liebherr.com
Koro Sharpening Service	61	(763) 425-5247	info@koroind.com	www.koroind.com
Liebherr Gear Technology Co.	5, 30	(734) 429-7225	info@lgt.liebherr.com	www.liebherr.com
LMT-Fette Inc.	6, 29	(800) 255-0852, (216) 377-6130	lmtfette@lmtfette.com	www.lmtfette.com
Marposs Corp.	8, 29	(888) 627-7677, (248) 370-0404	marposs@us.marposs.com	www.marposs.com
Metalcastello SpA	21	(39) 0534-205-11	export@metalcastello.com	www.metalcastello.com
Midwest Gear & Tool Inc.	20	(586) 754-8923	rosscr@attglobal.net	
Milwaukee Gear Co.	62	(414) 962-3532	support@milwgear.com	www.milwaukeegear.com
Mitsubishi Gear Technology Center	IBC	(248) 669-6136	info@mitsubishigearcenter.com	www.mitsubishigearcenter.com
Niagara Gear Corp.	17, 62	(800) 447-2392, (716) 874-9003	info@niagaragear.com	www.niagaragear.com
Overton Gear and Tool Corp.	24	(630) 543-9570	sales@overtongear.com	www.overtongear.com
Presrite Corp.	58	(216) 441-5990		www.presrite.com
The Purdy Corp.	59	(860) 649-0000	sales@purdytransmissions.com	www.purdytransmissions.com
Russell, Holbrook & Henderson Inc.	60	(201) 796-5445	sales@tru-volute.com	www.tru-volute.com
Schwartz Precision Gear Co.	62	(586) 754-4600	spgear@ameritech.net	
Star-SU LLC	29, 62, BOC	(847) 649-1450	sales@star-su.com	www.star-su.com
Timco Inc.	16	(800) 792-0030, (914) 736-0206	sales@timco-eng.com	www.timco-eng.com
Wiscon Products Inc.	62	(262) 639-2272	rolfe@wisconproducts.com	www.wisconproducts.com

This Room's a Mesh!

It's not likely to be found in any of this summer's catalogues, but the gear bed from The Rusted Lava Art Shop could lead to sweet dreams.

Chase Allen, owner of The Rusted Lava and designer of the bed, has been sleeping under gear teeth for a few years.

The concept of an industrial bedroom set came out of a trip to a local transmission shop. Allen visited the store to find scrap parts for his art and became enthralled with the idea of using gears in his decorating scheme.

"They're completely symmetrical," he says, "I salvaged my old bed, cut off the ugly headboard and drilled holes in the posts for the gears."

Though the creation has been functional for Allen, it is up for sale at a price of $775. Located in a Gullah house on Daufuskie Island, SC, the rest of the bedroom looks industrial with a headboard and shelves that are constructed out of a highly brushed steel.

For that romantic touch, Allen is also selling a candleholder made from old transmission gears. He found them at the same junkyard, painted them a bright yellow and welded metal into the center to hold a candle.

The rest of the artwork at this shop is equally unconventional. Allen learned most of his craft from an auto mechanic, who taught him the basics of welding. His artistic process involves finding scrap or sheet steel and seeing what ideas flow from there. He uses a torch to cut the steel, then bends and shapes it by hand before signing and dating each piece with the torch. At the foundation of each sculpture is rust, which Allen attains by spraying salt water over the surface, letting it rust naturally, then coating and painting the exterior.

All of this takes place in Allen's studio, which is a tent in the backyard of his house. Once the idea starts growing in his mind, it takes about a week to complete each masterpiece.

Gears are among the decorative touches that Allen is most comfortable with. Partially, that's because they're so abundant, as his mechanic frequently discards the ones that don't function. In the past, he found a pile of old gears and assembled them into the shape of a pig, which sold as a lawn ornament for $85.

"A friend suggested making a coffee table out of some gears. I might use them as the legs or as the tabletop and sell it for $500–600," he says.

Allen is open to any other creative uses for gears, whether as lawn or interior decorations. His work is mostly displayed on the porch of his house, but he also keeps pieces in numerous galleries and stores in the Carolinas. The 27-year-old artist started The Rusted Lava in 2001, buying all of his original supplies on a credit card until the folk art dollars started rolling in.

Daufuskie Island is only accessible by boat, so a portion of his business comes from customized work. If you have some extra gears and a one-of-a-kind innovation for them, he'd welcome the discussion.

"No request is too strange," he laughs.

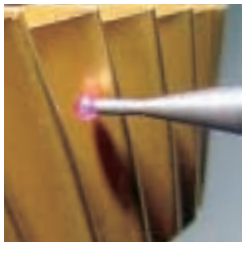
The Gearless Gear Shaper™

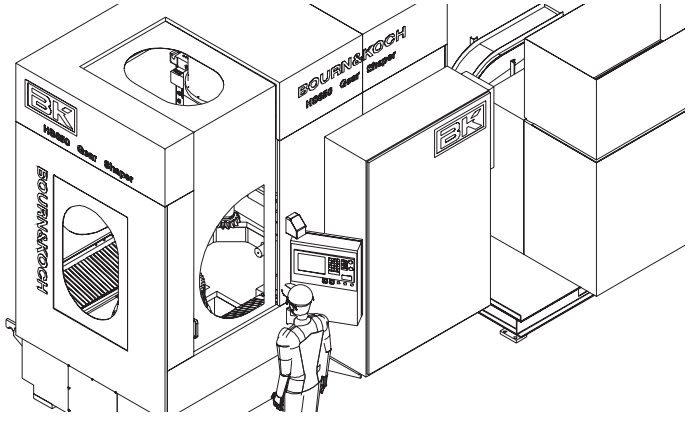
Bourn & Koch Fellows Division will introduce the new Gearless Gear Shaper™ gear shaping machine at IMTS 2004. The new design has 50% fewer mechanical parts than its FS series predecessors and is over 100 times more accurate on the transmission accuracy of the cutter and work axes.

Featured benefits of the new shaper design include:

- CNC Roll-Over™ external to internal gear
- Oriented Stiffness Back-Off™, CNC camless back-off
- Direct driven work and cutter spindles
- Single axis integration of positioning, stroke and Hydrostroke return ratio
- 300 mm vertical cutter spindle saddle travel
- CNC crowning
- Hydrostroke concentric force loading, quick return ratio, process monitoring, and adaptive force control features
- CNC guide
- State-of-the-art CNC control with GUI interface

Our wide range of standard and special shaper cutters and comprehensive services will bring your cost per piece down and your production in shape.





BOURN & KOCH Inc.

IMTS 2004

See us at IMTS for a cutting demonstration using Star SU shaper cutters. Booth B-6912 North Hall.

Star SU

Star SU LLC
5200 Prairie Stone Parkway
Suite 100
Hoffman Estates, IL 60192
Tel.: (847) 649-1450
Fax: (847) 649-0112
sales@star-su.com
www.star-su.com

GT 0504