GEAR TECHNOLOGY

MARCH/APRIL 2005

The Journal of Gear Manufacturing

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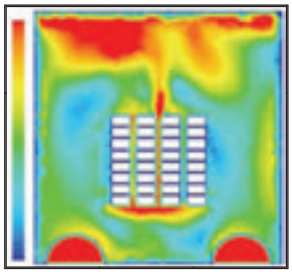
HEAT TREATING ISSUE



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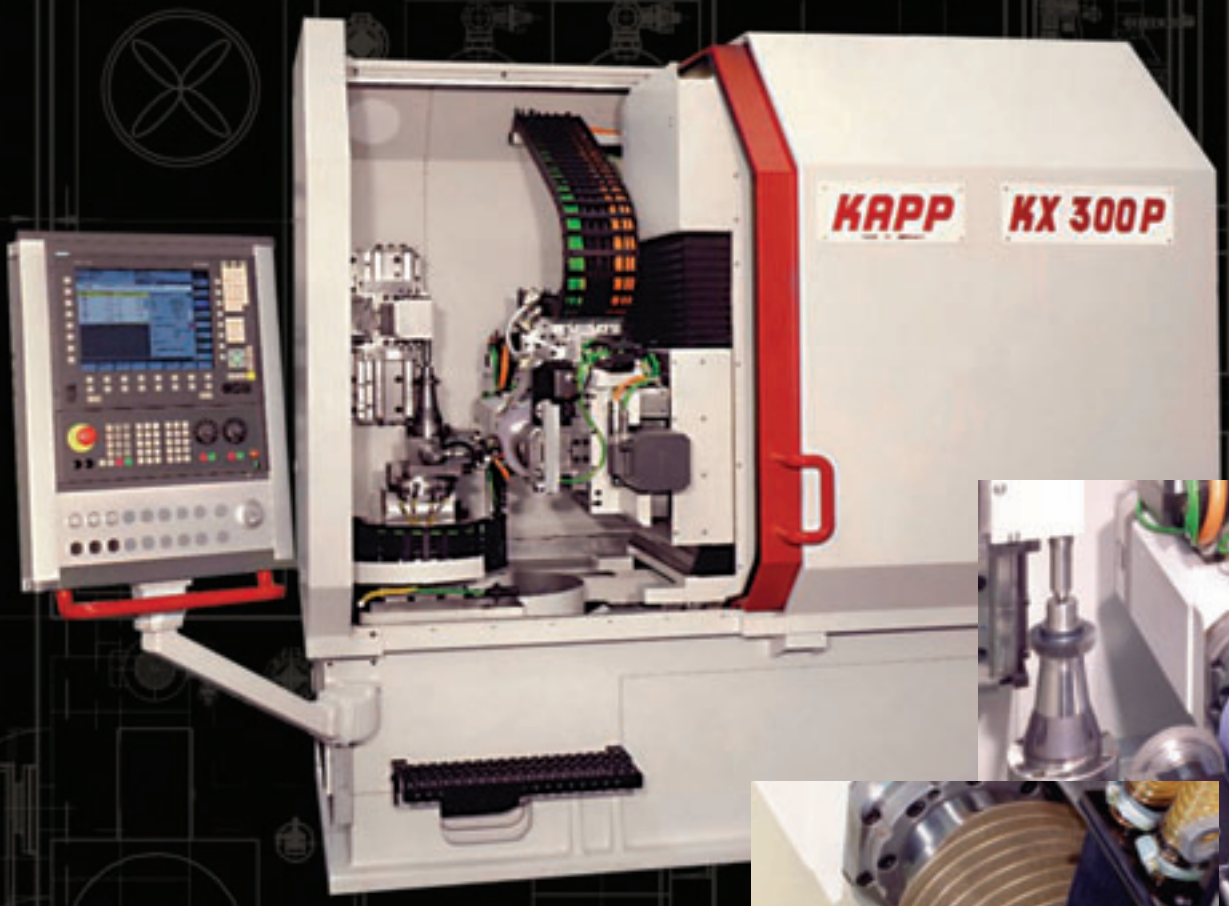
Cover photo courtesy of Nachi Machining Technology Co. of Macomb, MI.

The best is versatile



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The Journal of Gear Manufacturing

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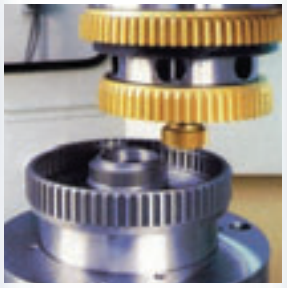

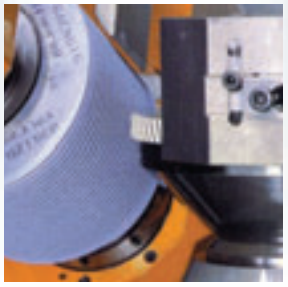

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Spring is in the air

In Chicago, Spring is finally in the air. Yesterday, we had our first truly balmy day, with temperatures in the 60s, the sun shining, a warm wind blowing, and birds chirping everywhere.

Over the past few weeks, conversations I've had with people in the gear industry make it seem that it's not just the weather that's warming up. The gear industry is also going through a healthy transition. Spring is finally coming to gear manufacturing.

Talking to both gear manufacturers and suppliers of gear cutting tools and machine tools, almost everyone in the industry seems to be extremely busy. Gear manufacturers are not only cutting gears, they're adding capacity. Cutting tool manufacturers are posting record sales. Gear machine tool manufacturers are filling up their capacity and looking into 2006.

In short, there appears to be growth in the industry again.

Roland Ramberg, president of The Gear Works—Seattle Inc., says that 2005 sales are "robust," that he expects to record his largest volume ever, by more than 10%. Ramberg says that a number of industries are driving demand, including most of the OEM heavy industries, material handling, conveyors, construction, mining, and printing. He also notes that the market for wind turbine gears has picked up considerably.

Cam Drecoll, president of Brad Foote Gear Works, says his business in 2005—and projected into 2006—is "booming," and that demand for gears in a number of key industries is also "booming." Those industries include wind turbines, locomotives, off-highway, steel and oil.

The story at Gear Motions Inc. is also extremely positive. Sam Haines, the company's president, says that 2005 will be his company's biggest year ever in terms of both sales and profits. Demand for hardened and ground gears is intense, especially in the automotive and motorcycle industries, Haines says.

Craig Ross, president of Midwest Gear & Tool, says that his sales were up 30% in 2004 and that he expects 2005 to be even better, with demand still strong among his machine tool, aerospace and military industry gear customers. In fact, Ross says, the only thing that might hold him back this year is the fact that he's in the process of moving to a new building.

Overton Gear & Tool has experienced double-digit sales growth over the past three years, according to company president Lou Ertel, and demand for his company's gears remains strong. Ertel expects that 2005 will be another growth year for Overton.

Forest City Gear is also building on a very strong 2004 and expecting a similar 2005, according to general manager Mike Goza. Forest City has picked up new customers since last year, and demand for gears in aerospace, motorcycles and fishing reels is keeping the company very busy.

I think you get the point. For many gear manufacturers, finding customers isn't the problem it was a couple of years ago.

But I don't want to give you the idea that everything is rosy, because it's not. I've talked to some gear manufacturers who are still struggling. Even those who are experiencing growth right now face significant challenges. Most everyone I spoke to said that one of their biggest problems is the rising costs of health care.

Some of the biggest challenges facing gear manufacturers are on the supply side. Most of them told me they're having a hard time getting their hands on raw materials, with delivery times for forgings as high as six months. More than one manufacturer also told me he was having a hard time getting gear steels, irrespective of price.

I also know, from talking to machinery suppliers, that if you think you might need to add capacity and you haven't already, you may have to wait in line.

Jeff Barnes, president of New England Gear, specializes in retrofitting gear machines. Barnes says he's full to capacity right now.

Gary Kimmet, VP of worldwide sales for Gleason Corp., says that both cutting tool and machine tool sales are "powerful," that 2005 is already shaping up to be a "great" year and that 2006 will likely be "very good" for Gleason. According to Kimmet, sales are strong both in the United States and Asia.

David Goodfellow, president of Star SU LLC, says that cutting tool sales were strong in 2004 and will be very strong in 2005 and that the demand is being driven by the automotive, construction and wind energy industries. Goodfellow also says that machine tool sales are expected to increase again this year.

The change of seasons is invigorating, especially when it seemed like the winter in the gear industry would never end. But now the gear industry appears to be poised for a period of needed growth. I'm really looking forward to the rest of 2005—and so should you!

Michael Goldstein, Publisher & Editor-in-Chief

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Adding High Velocity to High Pressure Gas Quenching

When gas quenching, the minimizing of heat treat distortion in gears may be a matter of high pressure *and* high velocity. That's what Solar Atmospheres thinks, that's why the heat treat company sends helium gas into its vacuum furnaces at more than 100 mph.

"The high pressure/high velocity gas quenching technology enables the gear manufacturer to finish machine gears closer to final size," says Robert Hill Jr., president of Solar Atmospheres of Western Pennsylvania, located in Hermitage. "This process has virtually eliminated post-heat treatment machining, grinding, straightening or plating to size for several types of gears, including many spiral bevel gears, worm gears, miter gears, and herringbone gears. Each of these types of gears has a propensity to severely distort during a traditional liquid quench."

Typically, gears made of low-alloy, medium-carbon steel (e.g. 4140) or of low-alloy, carburized steel (e.g. 8620) are hardened with hot oil as the quench medium. When liquid quenching is employed, three distinct phases occur. These phases produce large temperature differentials during the quenching process, so the roots, teeth, bores, shafts and webs cool at varying rates.

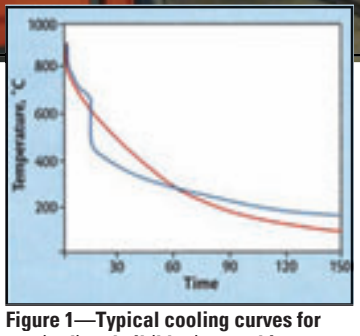

Figure 1—Typical cooling curves for gas (red) and oil (blue) quenching.

"These delta Ts cause tremendous internal stress on the gears, that will ultimately result in severe distortion," Hill says.

Instead of extracting heat by quenching in a liquid (e.g. water, salt, polymer or oil), vacuum furnace quenching uses inert gas cooling that subjects the gears to one cooling phase: convective (see Fig. 1). Since gas cooling is less abrupt and more uniform, this processing achieves acceptable hardened microstructures with considerably less distortion.

In the past, gas cooling wasn't fast enough to attain the proper metallurgical results. "Today, with increased pressure—10 bar—and increased velocity—primarily using helium, gas quenching is able to produce fully martensitic microstructures with much less distortion," Hill says. "However, there always exist certain limitations that may prevent a fully transformed phase. Therefore, for successful gas quenching, maximum cross sections and minimal percentages of elements within the alloy chemistry must be determined."

According to Hill, the use of helium for quenching is ever increasing, and improved cooling rates aren't only a function of pressure but also of gas velocity. By utilizing variable speed drives, Solar Atmospheres is now overspeeding its 300 hp blower

motors to 5,000 rpm. (Nominal speed is 3,600 rpm.) The exit gas velocity is now well over 100 mph. This quench gas impinges 360° around the workload and is then recirculated back through a heat exchanger.

"Since helium is a very light gas, the power required to recirculate it during quenching is far less than that used for nitrogen or argon," Hill says. "When cycle times—cooling times—are reduced by 40%, a substantial savings is realized."

Shape change is a leading cause of scrap and rework in the gear industry, so the value of vacuum heat treating is less spoilage. Vacuum quenching in the hardening process much reduces the distortion caused by residual stress.

Figure 2—Sample of parts processed using Solar Atmosphere's process.

Another advantage of high pressure gas quenching is its inert atmosphere. The heat-treated gears are bright, clean and oxide-free (see Fig. 2).

"There is a tremendous added value since gears no longer need to be pickled, shot- or grit-blasted, or ground," Hill says. "The surface condition of the gears remains the same as the pre-heat treated condition."

Since high pressure gas quenching eliminates the need for liquid quenchants and the parts are processed in an inert environment, vacuum heat treating is an environmentally friendly process.

"This technique is becoming more and more popular worldwide," Hill says, "especially when combined with the advantages of vacuum carburizing."

Solar Atmospheres Inc., a commercial vacuum heat treater, is advancing this technology. "Precise temperature controls, development of vacuum furnace capabilities and the demand for manufacturing efficiency are the driving forces," Hill says.

Also located in Souderton, PA, Solar Atmospheres has more than 30 vacuum furnaces—from lab size to large production—that serve the gear industry.

For more information:
Solar Atmospheres Inc.
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Hermitage, PA 16148
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Fax: (724) 982-0593
E-mail: *wpa@solaratm.com*
Internet: *www.solaratm.com*

Company Offers Technology for "Near-Frictionless Motion of Machines"

For "Near-Frictionless Motion"—Combined micro-relief (CMR) laps a part surface, such as this spline shaft, to create a hydrophobic effect, which works to keep oil droplets from spreading out. CMR also creates non-lapped grooves, which serve as reservoirs. Filled with oil, the reservoirs act as oil bearings and provide lubrication.

Friction Control Solutions Ltd. has a technology to reduce friction and wear, a process the company described as allowing "near-frictionless motion of machines."

The technology, called combined micro-relief (CMR), was designed to cope with extreme tribological conditions, including poor lubrication, high pressure, low-to-zero velocity and rapid directional changes.

CMR's ability to reduce wear and friction was checked through independent testing, says Kostia Mandel, FriCSo's vice president–R&D.

"These tests have been conducted by both FriCSo and by some of the leading manufacturers of various mechanical parts and systems, both in lab tests and in actual applications, including gear parts—like shafts and axles," Mandel says.

He couldn't discuss the manufacturers' specific applications or their test methods, though, because of binding nondisclosure agreements.

According to a FriCSo press release, the technology creates a highly stable, durable and uniform lubricant layer between moving surfaces. The process consists of lapping and grooving. The lapping is done with tools made of a polymeric compound with standard abrasive material. According to the company, the lapping creates a repelling force against the oil microlayer adherent to the countersliding part. This hydrophobic effect keeps the part afloat, away from the other part—even at a standstill.

"The hydrophobic characteristic is intrinsic to the CMR process and is not the result of applying foreign material," Mandel says.

The grooving, created with special software, is done through plastic deformation. The grooves are sinusoidal indents, with depths of a few microns. They aren't lapped, so they don't repel

oil. They instead serve as reservoirs for oil repelled by the part's lapped surface. Filled with oil, the reservoirs act as oil bearings and provide lubrication. According to the company, the grooving also strain hardens surface layers, increasing their hardness by 70–80%.

"FriCSo targets two major markets: automotive and heavy machinery," says Amir Guttman, managing partner at Aviv Venture Capital, which co-owns FriCSo. "The automotive market is huge, but penetration is slow. However, in the heavy machinery market—which includes shipping, oil drilling and military industries—we may generate sales during 2005."

An Israeli company, FriCSo was founded in 2003 and has offices in Farmington Hills, MI, near Detroit.

For more information:
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Fax: (248) 489-0832
E-mail: *info@fricso.com*
Internet: *www.fricso.com*

New Bevel Gear Cutting Machine from Gleason

The new Phoenix II 600 HC CNC cutting machine from Gleason features a monolithic column design that optimizes dry machining , reduces floor space requirements and improves cycle times.

According to the company's press release, this machine was designed for workpiece diameters as large as 600 mm. In addition, it can accommodate both wet and dry cutting processes as well as dry machining.

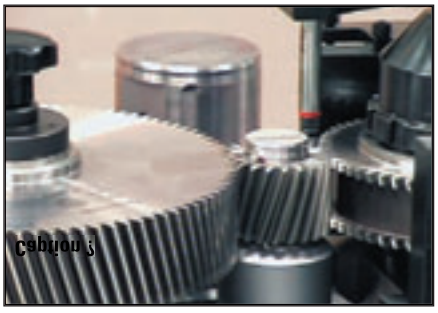
The need for a conventional machine bed is eliminated as this is the only machine in its class with a cast-iron monolithic column design. In addition, the cutter and work spindle are directly mounted to the column and the cutter spindle pivots to create the root angle rather than mounting the spindle on a rotating base. This enables hot dry chips to fall completely clear of the machine structure into a simple chip conveyor.

Other features include a direct-drive

spindle motor, higher acceleration/deceleration rates, increased torque, and shorter and faster axis motions to reduce non-cutting between cycles.

For more information, contact Gleason Corp. of Rochester, NY, by telephone at (585) 473-1000 or on the Internet at *www.gleason.com.*

New Gear Roller from Marposs



The M62 DF from Marposs is designed for the dynamic inspection of ring gears with automatic part rotation.

The system can evaluate lead angle, lead variation and taper in addition to the usual double-flank parameters.

According to the company's press release, additional features include a retoolable center distance from 25–200 mm; the ability to accommodate a tooth module up to 5, part height up to 60 mm, and weight up to 10 kg; low pressure measuring devices and an electric gear axis generated by dedicated transducers.

New Gearboxes from ZF

The new right-angle servoworm gearboxes from ZF are designed to meet the demands of servo drive applications.

According to the company's press release, the units are available with high precision, precision and standard levels of accuracy that offer backlash levels of less than 1, 3 and 10 arc-min. respectively. Units are sealed with a high-performance polyglycol lubricant.

Featuring a computer-optimized gear contact pattern that evenly spreads the stress throughout the teeth, these units also can perform at less than 55 dB. The worm wheel is manufactured from a specially developed bronze alloy.

The oversized taper roller bearings have a configuration that consists of two sets of roller bearings and an additional set of floating ball bearings. Bearings are preloaded for higher temperature variations and loads.

Connection to the drive shaft is accomplished through a keyless shrink disc, while a pinned and bound wheel ring design promotes a stiff and reliable interface.

For more information, contact ZF Industrial of Nottingham, U.K., by e-mail at *rob.pearson@zf-group.co.uk.*

New Size 17 Gearhead from HD Systems

The Quantam Series from HD Systems is the highest torque capacity harmonic gearhead the company has produced.

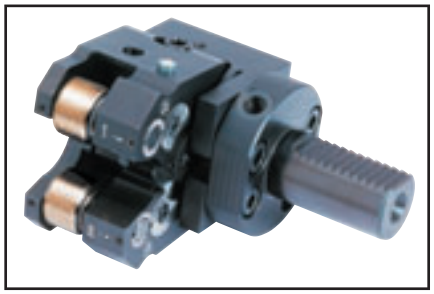
According to the company's press release, this gearhead delivers 50% more torque than the CSF Series. It can maintain 1 arc-min. positional accuracy and +/–5 arc-sec. repeatability.

With an outer diameter of 79 mm and a length measurement of 45 mm, the gearhead is available in ratios of 50, 80, 100 and 120:1.

For more information, contact HD Systems of Hauppauge, NY, by telephone at (800) 231-HDSI or on the Internet at *www.HDSI.net.*

New Thread Rolling Heads from LMT-Fette

The new tangential thread rolling heads from LMT-Fette are pre-

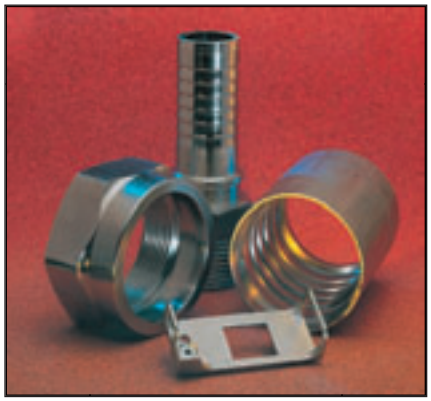


sychronized for efficient set-up with no roll timing. According to the company's press release, because symmetrical roller repositioning is performed with a central setting screw and away from the rolling systems, operators can expect a 10-minute cycle time.

The lengths of the rolling heads have also been decreased by 20% in order to be suitable for use in CNC lathes and screw machines. Available in T120F, T160F, T220F and T350F, these heads can accommodate thread diameters from 5/64–2". Models can now thread 1/16–1" diameter NPT and NPTF pipe sizes.

For more information,
contact LMT-Fette of Cleveland, OH,
by telephone at (800) 225-0852
or on the Internet at *www.lmtfette.com.*

New Lab Oil from Heatbath



Lab Oil 100 100 is dry-to-the-touch over phosphate coating, low in toxicity, has improved emulsification and high corrosion resistance. The product is designed for manufacturers of metal products requiring rust or corrosion protections.

According to the company's press release, emulsions of oil can withstand 240+ hours of per ASTM B-01117 when applied over zinc phosphated steel panels. Maximum corrosion protection is achieved when concentration is maintained at 20–30% by volume.

In addition, this oil is tolerant of alkaline or acid contamination when either is encountered in black oxide or phospating cycles.

Recommended operating temperature is 140–180° and concentration ranges from 5–30%. The typical immersion time is 1–2 minutes and tanks can be mild steel, heated with steam or gas and electric heater.

For more information,
contact
Heatbath Corp. of Springfield, MA,
by telephone at (413) 452-2000.

New Furnace from Grieve

The No. 943 pit furnace from Grieve is an electrically-heated top loading pit furnace capable of 2,000°F and is suitable for heat treating applications at a customer's facility.

Additional features include 7" thick insulated walls, an air-operated vertical lift door and reinforced ½" steel top plate, a temperature controller and separate heating element control contactors.

For more information, contact
The Grieve Corp. of Round Lake, IL,
by telephone at (847) 546-9210
or on the Internet at
www.grievecorp.com.

William R. Stott, Managing Editor

Photos courtesy of Blaser Swisslube (top left) and ITW Rocol North America

Environmentally

FRIENDLY CUTTING FLUIDS

"We were doing some hard skiving, and tool life was a big issue," says Kevin Lynch, business unit manager for gear manufacturer ITW Spiroid. The Glenview, IL-based company recently switched from a mineral oil-based cutting fluid to a vegetable oil-based fluid. "The cutting tools are really expensive, so we switched to it, and we actually saw about a 30% increase in tool life."

ITW Spiroid, like many gear manufacturers and other metalworking companies, is finding that many of today's more environmentally friendly industrial fluids are actually making their biggest impact not in environmental terms, but in performance.

"We really didn't do it for the environmental aspects," Lynch says. The key for them was increasing tool life, but the environmental benefits were an added bonus.

ITW Spiroid uses the vegetable oil-based Accu-Lube Flood 40 coolant from sister company ITW Rocol.

Tools for Reducing Environmental Impact

Today's formulators of industrial chemicals have a wider array of tools than ever, from new types of synthetic esters to new breeds of genetically modified vegetable oil crops. This means a greater ability for manufacturers to tailor fluids to their exact metal cutting needs.

So manufacturers are able to increase productivity, achieve a better surface finish, or—like ITW Spiroid—improve tool life, all while improving the work environment for their employees and reducing the costs associated with disposing of waste fluids.

Many coolant suppliers offer some choices that are more environmentally friendly than others. In some cases, a more environmentally friendly product is simply one that can be recycled or that lasts longer. If you have to dispose of less waste fluid, you have less impact on the environment.

"A lot of people consider that even a mineral oil-based product can be environmentally friendly, through extended sump life or by formulating with chemistries

that aren't hazardous to aquantic or plant life," says Randy Templin, vice president of Blaser Swisslube. Blaser supplies both traditional mineral oil-based products and the Vasco line of vegetable oil-based products. But, Templin adds, "We consider ourselves to be a leader in marketing products based on natural and synthetic esters that are derived from a vegetable base."

Vegetable Oils

Metalworking fluids based on vegetable oils are available as straight oil (as in the case of the Accu-Lube Flood 40 fluid used by ITW Spiroid) or as water soluble products, where a concentrate is mixed with water to produce the coolant. But no matter which form the fluid comes in, vegetable oils have a number of performance benefits over straight mineral oils.

"In general, we can get better lubricity with a vegetable based-oil than we can with a straight oil," says Robert Myers, business unit manager for the Accu-Lube product line. The extra lubricity is what gives manufacturers better tool life, he adds.

Blaser has seen increased demand for its vegetable oil-based products, especially in Europe, where higher environmental concerns, regulations and disposal costs require manufacturers to use coolants without chlorine. "When you take the chlorinated additive out of a cutting fluid, you give up considerable performance, and with some materials, it can be dramatic," Templin says. "The vegetable oils offer much higher lubricity than mineral oils, so you're able to machine chlorine free."

In addition to greater lubricity, vegetable-based products offer many advantages over traditional mineral oils, says Templin. Among those advantages are a higher flash point, which means less chance of fire; less misting than mineral oil; and better compatibility with skin.

Another company using vegetable-based products to push the performance envelope is Environmental Lubricants Manufacturing Inc. (ELM) of Plainfield, IA. ELM produces the SoyEasy line of industrial fluids, which are based on genetically modified soybean oil. The modified soybean produces an oil that resists oxidation and lasts longer in the sump, according to Gene Tripp, director of sales and marketing.

Tripp has been working for several years with a number of well-known agricultural, off-highway, automotive and aerospace companies, testing his company's coolants for gear manufacturing operations.

"We've tested on a broach, on a shaper cutter, and on a finish shaving cutter operation," Tripp says, "and we've done very well."

Besides being biodegradable and recyclable, vegetable oil-based products, offer longer tool life, higher feeds and speeds and improved surface finish of parts, Tripp says.

"These products are environmentally friendly, and they're extremely lubristic, without the harmful additives, he says." "They offer less mist, less foam, less chance of fire. They're high performance products that will exceed petroleum and are extremely stable."

The company's major gear customers are still in the proving stages, but ELM has a number of non-gear customers who have achieved significant tooling savings by switching to the SoyEasy, Tripp says.

Reduce, Reuse, Recycle

In addition to raising performance, one of the goals among coolant suppliers is to help manufacturers reduce the amount of fluid that's disposed.

"That's our drive—our obsession—to produce a zero waste stream," says Hank Limper, general manager of the metal cutting fluids division of Houghton International.

"What we felt was the golden fleece of this industry was metalworking fluids that would not go rancid, that would not sour, that basically would last 'forever,'" Limper says.

Typically, a company disposes of metalworking fluids because of biological activity that breaks them down, causes odors and dramatically reduces the sump life of the fluids, Limper says.

So Houghton developed the HOCUT 795 line of metalworking fluids, a water soluble product, based on what Limper describes as a "bio-stable building block," a chemical ingredient that helps the fluids last longer and also allows them to be used for a variety of applications.

Starting with the bio-stable base material, Houghton can modify the formulation to suit a user's needs. "We can add a lot of mineral oil and make it a soluble oil, we can use less mineral oil and make it a semi-synthetic, we can add synthetic components like polymers and make it a synthetic product offering, or we can add vegetable oil and make it a truly vegetable oil-based product," Limper says.

But the key to being environmentally friendly is the ability of the water soluble products to be reused and recycled, Limper says. Houghton uses what they call a "congruent chemistry approach." That means that a wide variety of industrial fluids, including quench oils, spray wash cleaners, rust inhibitors and coolants, are all based on the same bio-stable building block. The idea is that when certain fluids become too contaminated for further use, instead of dumping fluid into the waste stream, it gets filtered, processed and put back into a central coolant system.

"The theory is that you could tie all your process chemicals into the central coolant system," Limper says.

Reducing waste can save a company a lot of money, he adds.

In fact, Houghton worked with a major U.S. manufacturer of aerospace gears to implement a rigorous fluids management program that included replacing the company's old coolants and processes with a central system using HOCUT 795. That facility reduced its hazardous waste disposal by 95%, saving the company $66,000 per year.

Okay, So Why Isn't Everybody Going Green?

It would be easy to switch to more environmentally friendly cutting fluids if all manufacturers had to think about were the enhanced performance, environmental benefits and reduced waste. The main disadvantage of all these products is price.

The cost differences range depending on what the customer is using, says Blaser's Templin. Some of the refined mineral-based cutting oils, particularly recycled oils, can be as little as one-fifth the cost of Blaser's vegetable-based

Courtesy of Houghton International

Courtesy of Environmental Lubricants Manufacturing Inc.

Courtesy of Houghton International

products. In most cases, the price disparity isn't that great, Templin says, but it's not uncommon for the vegetable based-products to cost as much as 50% more.

That price differential means that nobody is willing to pay just for the environmental benefits, Templin says. "Environmental concern might drive their interest, but they have to justify it by performance."

Blaser has conducted a number of studies on gear manufacturing operations to demonstrate the performance and cost benefits of the vegetable-based cutting fluids. In one study, which involved hobbing transmission gears, tool life was measured in actual production runs over a two-month period. A variety of gears were cut using both a mineral-oil based coolant and Blaser's Vascomill 42 vegetable oil-based coolant. In all cases, the tool life achieved with the vegetable oil-based coolant was significantly higher (averaging 45% greater tool life over two months).

In another Blaser study involving transmission parts, tool life was increased by 40%, even while feeds were increased so that cycle time per piece was reduced by 30%.

Other customers have replaced mineral oil with Vascomill for performance improvements in gear shaping, milling, shaving and broaching operations, Templin says.

Although the additional price can't always be justified, in many operations, the more expensive fluids offer a clear-cut advantage.

"Consistently, customers tell us that when you look at the whole picture, the price per gallon pales when compared to tool life savings and the reduced usage and consumption," Limper says. "Those things are part of the total cost picture that the intelligent customer is measuring."

Beyond price, there may also be some resistance in the marketplace due to early attempts to introduce vegetable-based products.

"Biological populations—bacteria—love vegetable oil," Limper says. "It's literally Thanksgiving dinner for them. People would move to this technology and find the product being waste treated right in the sump, because the bacteria would tear it apart and have a field day with it."

But the vendors all agree that the oxidation problem of the early vegetable products has largely been overcome through a combination of technological improvements, including better basic materials, such as Houghton's biostable building block or ELM's genetically modified soybean oil. Also, the fluids are now formulated with highly specialized additive packages that help reduce the biological activity.

"Some of our original customers that are now seven years old still claim that most of their machines have never been dumped or discharged due to failure of the coolant," Limper says.

The vendors also agree that demand for more and more environmentally friendly cutting tools will continue to grow.

"I believe it's definitely a market that's growing," Templin says. "As people replace older equipment with newer technology, they're demanding more out of the fluids themselves, and they're paying more attention to the oils they're using. In addition to that, the environment, health and safety are becoming more and more important to the customers."

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Advances in Quenching

A Discussion of Present and Future Technologies

D. Scott MacKenzie

Management Summary

Heat treating and quenching are arguably the most critical operations in the manufacture of gears. It is these processes that provide a gear with the proper mechanical and wear properties to withstand high contact stresses and have high longevity. Unfortunately, heat treating and quenching are often the least understood in the manufacturing stream. Parts are often distorted or stained after heat treatment. It is often the "black hole" on which all the ills of the manufacturing process are blamed.

It is the purpose of this article to examine the causes of distortion during the heat treatment and quenching of gears and provide some insight into proper action to correct distortion and high residual stresses during quenching.

Introduction

Regardless of the product, it is likely that it is heat-treated and quenched. Engine components are heat treated for wear and durability. Aircraft components are heat treated for strength and fracture toughness. Even bicycle frames are heat treated for strength, lightness and durability. Furnaces are specially designed to heat treat products quickly and cost-effectively. To meet these needs, it is necessary to expand the knowledge of heat treating and quenching to consistently produce a quality product, capable of being manufactured in a cost-effective manner.

In metallurgy, the definition of quenching is "the controlled extraction of heat." The most important word in this definition is "controlled." The quenchant is any medium that extracts heat from the part. The quenchant can be a liquid, solid, or gas.

When a hot component comes in contact with a liquid quenchant, there are normally three stages of quenching (see Fig. 1):

- Vapor Stage (Stage A or Vapor Blanket Stage)
- Boiling Stage (Stage B or Nucleate Boiling Stage)
- Convection Stage (Stage C)

The vapor stage is encountered when the surface of the heated component first comes in contact with the liquid quenchant. The component becomes surrounded with a blanket of vapor.

In this stage, heat transfer is very slow and occurs primarily by radiation through the vapor blanket. Some conduction also occurs through the vapor phase. This blanket is very stable, and its removal can only be enhanced by agitation or speed-improving additives. This stage is responsible for many of the surface soft spots encountered in quenching. High-pressure sprays and strong agitation eliminate this stage. If the surface spots are allowed to persist, undesirable microconstituents can form.

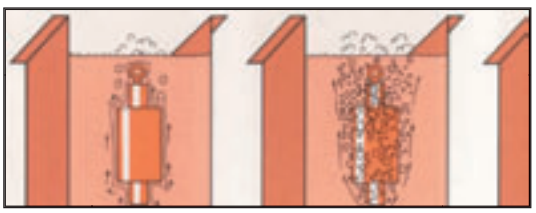

Figure 1—Schematic representation of the three stages of quenching for normal quench oil: 1) Left—vapor barrier formation; 2) Center—vapor barrier collapse and nucleate boiling; 3) Right—convection.

The second stage encountered in quenching is the boiling stage. This is where the vapor stage starts to collapse and all liquid in contact with the component surface erupts into boiling bubbles. This is the fastest stage of quenching. The high heat extraction rates are due to heat being carried away from the hot surface and transferring it further into the liquid quenchant, which allows cooled liquid to replace it at the surface. In many quenchants, additives have been utilized to enhance the maximum cooling rates obtained by a given fluid. The boiling stage stops when the temperature of the component's surface falls below the boiling point of the liquid. For many distortion-prone components, high-boiling-temperature oils or liquid salts are used if the media is fast enough to harden the steel, but both of these quenchants have relatively little use in induction hardening.

The final stage of quenching is the convection stage. This occurs when the component has reached a point below that of the quenchant's

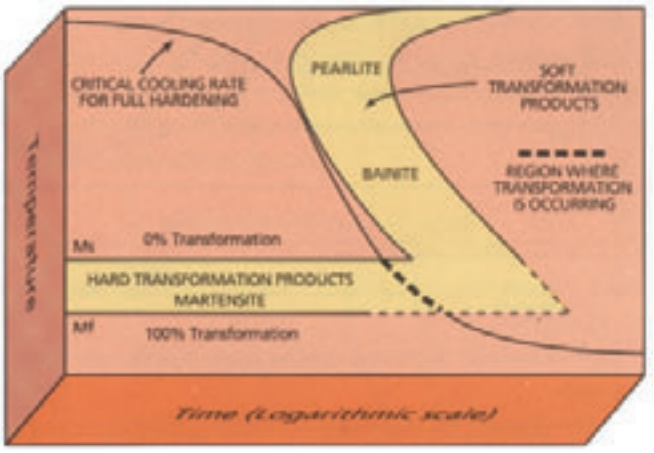

Figure 2—A time-temperature-transformation (TTT) diagram illustrating the critical cooling rate for complete martensitic transformation.

boiling temperature. Heat is removed by convection. It is controlled by the quenchant's specific heat and thermal conductivity, and the temperature differential between the component's temperature and that of the quenchant. The convection stage is usually the lowest of the three. Typically, it is this stage where most distortion occurs.

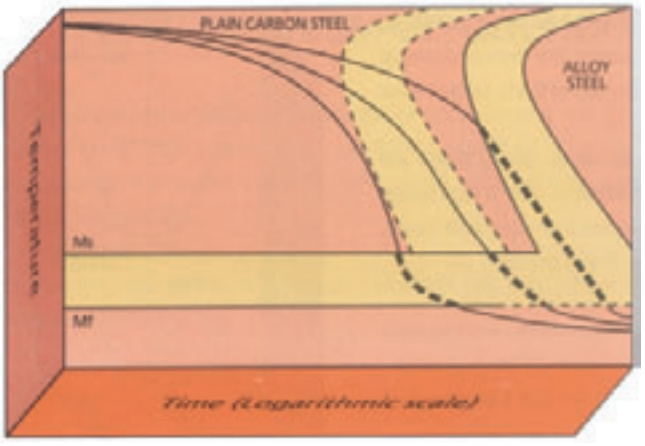

Figure 3—The effect of alloy content on steel hardenability.

Obtaining desired properties and achieving low distortion is usually a balancing act. Often, optimal properties are obtained at the expense of high residual stresses or high distortion. Low distortion or low residual stresses are usually obtained at a sacrifice in properties. Therefore, the optimum quench rate is one where properties are just met. This usually provides the minimum distortion.

Table 1—Martensite Start Transformation Temperature (M_s) as a Function of Carbon Content.

Carbon Content M_s	Temperature
0.2%	430°C
0.4%	360°C
1.0%	250°C

To achieve proper strength and toughness, it is necessary to convert austenite to martensite, which is then altered to form the proper tempered martensitic microstructure. To achieve this conversion of austenite to martensite, a rapid quench rate is required. This quench rate must be fast enough to avoid the formation of upper transformation products, like bainite and pearlite, and convert all austenite to martensite. This critical quench rate just misses the "knee" of the time-temperature-transformation (TTT) curve (Fig. 2). The rate of the critical quench rate is dependent on the steel chemistry.

In practice, when a steel component is quenched, the surface cools much more rapidly than the center. This means that the surface could cool at the critical rate and be fully hardened, but the center cools more slowly and forms a soft pearlitic or bainitic microstructure.

Hardenability is the ability of steel to through-harden. It is not the ability of the steel to harden. In a sense, it is a measure of the critical cooling rate on the TTT curve.

Increasing the hardenability of steel is accomplished by increasing its alloying content. Manganese, chromium and molybdenum are all effective alloying elements that increase a steel's hardenability. These elements cause a delay in transformation by shifting the transformation curve to the right. This reduces the critical cooling rate for martensitic transformation (Fig. 3). However, alloying elements may be expensive and not always beneficial to other processes, such as machining or forging.

Increasing the alloying content is not a simple panacea. Increasing the carbon and alloying content can also have deleterious effects by lowering the martensite-start transformation temperature (M_s). Increasing the carbon content, while shifting the TTT curve to the right, significantly lowers the M_s temperature (Table 1). Alloying elements also increase the "effective carbon" content according to the following formula (Ref.1):

$$C_{eq} = C + Mn/5 + Mo/5 + Cr/10 + Ni/10$$

Cracking and distortion increase along with the "effective carbon" content. Alloys become prone to distortion and cracking as the "effective carbon" content exceeds 0.52%. This tendency is decreased by the proper application of quenchants. A quenchant is used that is fast enough to achieve the desired properties, but slow enough that cracking or excessive distortion will not occur.

The cooling characteristics of a quenchant can be measured using probes instrumented with thermocouples. Various techniques have been used, including both cylindrical and spherical probes manufactured from a variety of metals, including stainless steel, silver and nickel alloys. One of the most widely used and accepted methods is based upon the use of a 12.5 mm diameter cylindrical probe manufactured from Inconel 600® alloy, as specified by the Wolfson Heat Treatment Center (WHTC) Engineering Group, recommended by the International Federation for Heat Treatment (IFHT) and adopt-

ed by the International Standards Organization (ISO 9950).

Results obtained by the different test methods vary depending upon the material, geometry and surface condition of the probe. Cooling curves produced in this way illustrate well the three stages of quenching and demonstrate the influence that factors such as agitation, quenchant temperature, contamination and degradation have upon quenching performance.

The cooling characteristics can either be shown as a graph of temperature against time or as a graph of temperature against cooling rate, as shown in Figure 4 for both normal speed and high speed quenching oils.

The duration of the vapor phase and the temperature at which the maximum cooling rate occurs have a critical influence on the ability of the steel to harden fully. The rate of cooling in the convection phase is also important since it is generally within this temperature range that martensitic transformation occurs. Therefore, it can influence residual stress, distortion and cracking.

However, cooling curves produced under laboratory conditions must be interpreted carefully and should not be considered in isolation. Results on used quenchants should be compared with reference curves for the same fluid.

Oil Quenchants

It is not known how long oils have been used in the hardening of ferrous alloys. Many types of oils have been used, including vegetable, fish and animal oils, such as sperm whale oil. The first petroleum-based quenching oils were developed around 1880 by E.F. Houghton in Philadelphia. Since that time, much advancement has been made in the development of quenching oils to provide highly specialized products for specific applications.

A wide range of quenching characteristics can be obtained through careful formulation and blending. High quality quenching oils are formulated from refined base stocks of high thermal stability. Selected wetting agents and accelerators are added to achieve specific quenching characteristics. Complex antioxidant packages are included to maintain performance for long periods of continued use, particularly at elevated temperatures. Emulsifiers may be added to enable easy cleaning after quenching.

Petroleum Oil-Based Quenchants

Petroleum-based quench oils can be divided into several categories, depending on the operational requirements. These requirements include quenching speed, operating temperatures and ease of removal.

The quenching speed is important because it influences the hardness and the depth of hardening. This is probably the most common method of classifying quench oils. They can be classified as normal, medium or high speed.

Normal speed quench oils have relatively low rates of heat extraction and are used in applications where the material being quenched has a high hardenability. Highly alloyed steels, such as AISI 4340, or tool steels are typical examples of steels quenched in normal speed oils.

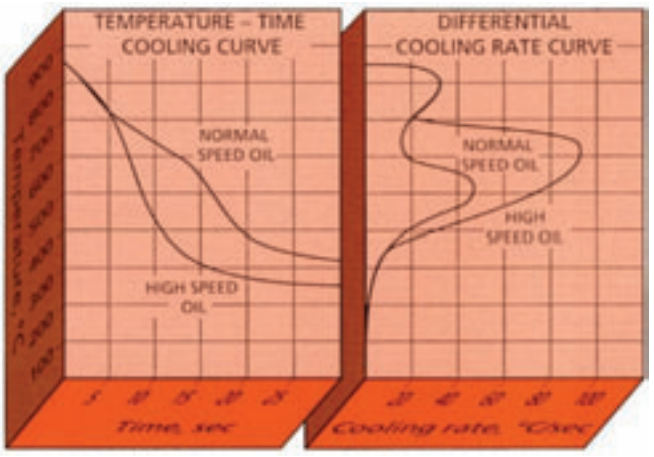

Figure 4—Temperature-time cooling curve and the differential cooling rate curve.

Medium speed quench oils provide intermediate quenching characteristics and are widely used for medium to high hardenability applications where dependable, consistent metallurgical properties are required.

High speed quench oils are used for applications such as low hardenability alloys, carburized and carbonitrided components, or large cross-sections of medium hardenability steels where high rates of cooling are required to ensure maximum mechanical properties. A comparison of the quenching speeds of the different types of quench oil is shown in Figure 5.

Marquenching oils are a special case where the part is quenched at elevated temperature, typically 100–200ºC. The workpiece is held in the quenchant until temperature equilibrium is established throughout the section, and then air-cooled to ambient temperature.

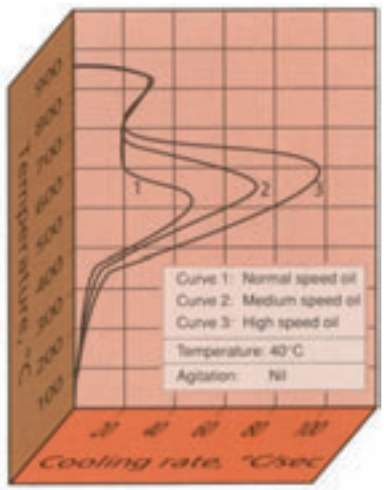

Figure 5—Cooling curves for normal, medium and high speed quenching oils.

During marquenching, components are quenched to an intermediate temperature close to the M_s temperature and held at this level. This eliminates the temperature gradients across the surface. Consequently, during subsequent slow cooling after removal from the hot oil, transformation to martensite occurs uniformly throughout the section. This minimizes the generation of internal stresses and reduces distortion.

Since marquenching oils are used at relatively high temperatures, their formulation and physical properties are different from cold quenching oils. They are formulated from very carefully selected base stocks with high oxidation resistance and thermal stability. They have high flash points and viscosities and

contain complex antioxidant packages to provide long life. Selection of the marquenching oil is based on the operating temperature and quenching characteristics. A minimum of 50ºC should be maintained between the operating temperature of the oil and its flash point.

However, the source of distortion and residual stresses is not limited to the martensite start temperature, the oil used, or the alloy content. There are a number of sources of residual stresses, and not all of them are heat treating-related. A schematic of some causes of distortion and residual stresses is illustrated in Figure 6.

Figure 6—Fishbone diagram of the potential causes of residual stresses and distortion.

Distortion and Residual Stresses

By far the largest source of problems for heat treaters is distortion of parts after heat treatment. Distortion causes excessive noise in the gear drive train and potentially early failure due to high residual stresses. It can be seen in Figure 6 that many of the sources of residual stress and distortion occur before heat treatment and quenching, yet it is often the heat treater that gets the blame for a distorted part.

Material. The alloy chosen can play an important role in how sensitive a part is to distortion during quenching. If the equivalent carbon C_{eq} is greater than 0.52%, it is prone to high residual stresses from transformation stresses and cracking (Ref. 1). If it has low hardenability, fast quench rates are required to meet properties. This can also cause residual stresses because of the development of thermal gradients during quenching that can cause some areas to transform to martensite earlier than other areas. Segregation in the raw material can cause local areas of high hardenability, which can also cause localized early transformation to martensite, creating metallurgical notches that are prone to cracking.

Design. Often the design of a part is responsible for cracking or distortion. For instance, if sharp radii are used or there is little transition between thick and thin sections, a high level of constraint forms. This can result in distortion or cracking. It is always a good idea to use generous transitions between sections and minimize the use of thick and thin sections.

Prior to heat treatment. Many processes, such as forging and casting, create large residual stresses during the formation of the green shape. This is due to the elevated temperatures, the non-uniform deformation, and the subsequent non-uniform cooling. Different microstructures are formed. This will cause non-uniform response to heat treatment. Also, because of the non-uniform deformation that occurs during forging, significant residual stresses are formed. To relieve these stresses, it is always recommended to normalize the forgings prior to machining. This serves two purposes—first to provide a semi-uniform microstructure (ferrite and pearlite) for machining and secondly to reduce the residual stresses occurring during forging.

One practice that is always recommended, but is rarely implemented, is to spheroidize anneal the parts after normalizing. This practice causes the carbides in the pearlite to form uniformly distributed carbide spheres. This makes a steel much easier to machine, and it forms chips readily. The material is softer, more uniform, and has a better surface finish. Tool life is improved. As an added benefit, response to heat treatment is also much more uniform and consistent. Typical spheroidizing cycles are long (10+ hours) and at elevated temperatures (1,250–1,325°F). Because of the time involved and the cost of furnace time, this valuable step is often skipped.

In the case of castings, the solidification rate is non-uniform, meaning that there will be localized segregation and that the concentration of alloying elements will not be uniform throughout the part. During heat treatment, this non-uniformity will cause different hardness responses and variable distortion. Often the castings are homogenized to reduce the local chemical gradients. It is also recommended that a normalization anneal is performed to increase homogeneity of the microstructure.

Many of the processes prior to heat treatment involve the removal of material. These can include grinding, broaching, turning, and other machining operations. Because of the speed and feed rates at which these operations must operate to be profitable, a large amount of residual stresses can be created in the part. The stresses will be relieved during heat treatment, resulting in part distortion. To minimize the formation of residual stresses, it is often necessary to turn the part over several times during the machining operation. It is also often necessary to include several stress relief operations during the machining operations. The amount of residual stresses created in a shop is highly dependent on its various practices. This includes tool sharpening frequency, feeds and speeds, the coolant used, geometry of the tool, etc.

Heat treatment. Parts containing residual stresses prior to heat treatment will relieve those stresses during heat treat-

ment. The relaxation of these stresses will cause distortion as the part finds a stress-free equilibrium. Heat-up rates in the furnace can also cause distortion, as thermal gradients are formed and the thinner sections reach temperature quicker. There will be differential thermal expansion, which can cause sizable thermal strains to be developed within the part. If these thermal strains are large enough, then plastic deformation and distortion can occur. The use of a preheat stage to allow thicker sections to "catch-up" to the thinner section will reduce distortion. The same thing can occur if the furnace has non-uniform temperature within the work zone.

Racking of parts is an extremely important part of the heat-treating process. Proper racking minimizes part-to-part interactions and allows heat to reach all parts. It further allows the quenchant to evenly extract the heat from parts in a uniform fashion.

The role the atmosphere plays is often overlooked in the control of distortion and residual stresses. Most gears are carburized to achieve a hard wearing surface. In non-wear critical areas, carburizing is not needed. These regions are plated or coated with a carburizing stop-off to prevent the diffusion of carbon into the steel. As steel transforms from austenite to martensite, there is a volumetric expansion that increases as the carbon content increases:

$$\Delta V/V \times 100 = 1.68(100 - V_c - V_a) + V_a(2.21C - 4.64)$$

where ΔV is the change in volume; V_c and V_a are the volume fractions of carbon and austenite; and C is the concentration of carbon in the steel (Ref. 2). Typically this amount is between 3–5% for carburized steel. This volume change will cause differential transformational strains, which may cause distortion. While these strains may not cause distortion to occur immediately after heat treat, distortion can appear immediately after any subsequent machining steps, as the part tries to achieve a new static equilibrium. These residual stresses can also manifest themselves by shortened fatigue life.

Proper atmosphere control is important. Excessive soot can be carried into the quench oil, creating dirty parts, and shortening the life of the quench oil. Proper atmosphere control can also reduce the amount of retained austenite, which can also cause residual stresses and distortion.

Quenching. From Figure 6, it can be seen that there are many sources of residual stress and distortion. In quenching, the primary source of distortion and residual stresses is differential temperatures from the center of the part to the surface or from different locations on the surface. By reducing the thermal gradients and differential temperatures, large reductions in residual stresses and distortion can be achieved. The most significant factors that cause large thermal gradients in parts during quenching are temperature, agitation, the quenchant chosen and contamination of the quenchant.

Temperature. Increasing the oil temperature can reduce the distortion and residual stresses in a heat-treated component. As the oil temperature is increased, the temperature gradients in the part are decreased. This is the basic principle of martempering. Using increased temperature can also reduce thermal gradients in cold oils, up to the recommended use temperature of cold oil (typically 180–200ºF). Interestingly, the speed of cold oil can be increased by warming to approximately 160ºF.

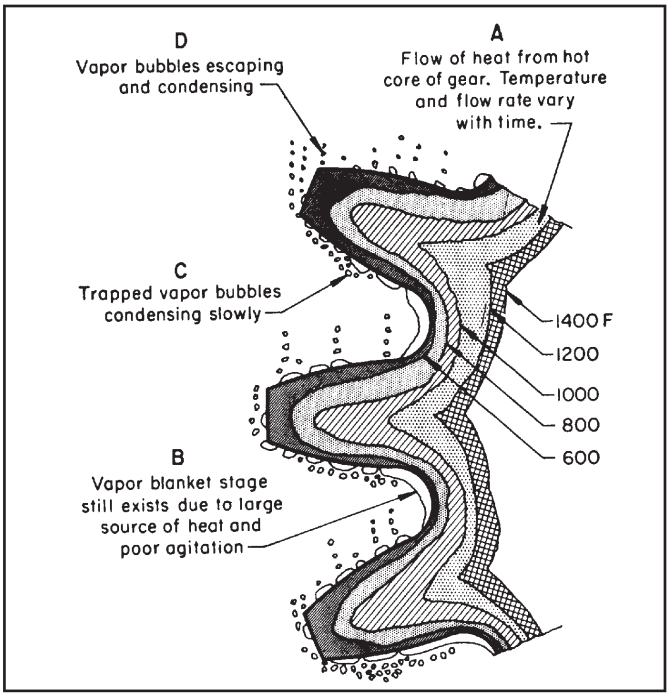

Figure 7—Creation of non-uniform quenching by inadequate agitation (after Ref. 3).

Agitation. Distortion occurs because of differential (Ref. 3.) temperature gradients, whether from the center to the surface or from surface to surface.

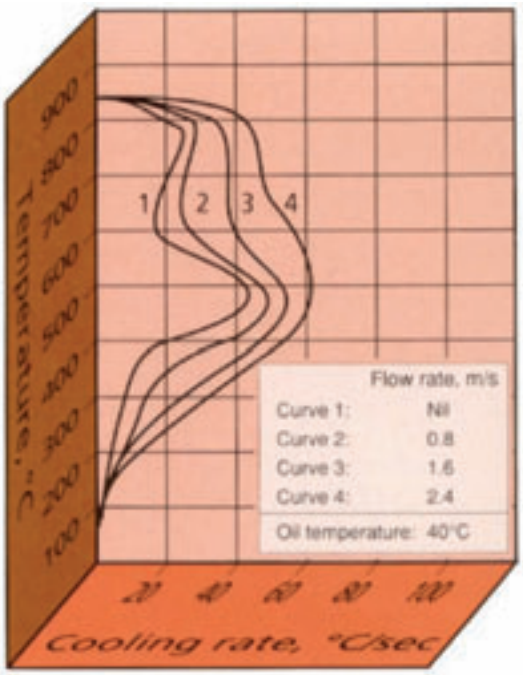

Figure 8—The effect of agitation on the quenching characteristics of a normal speed oil.

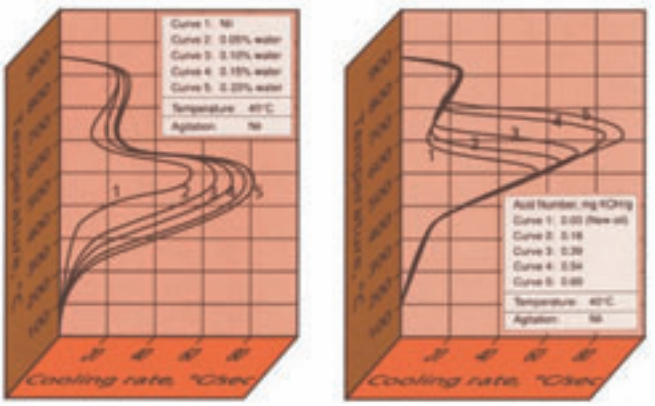

Figure 9—The effect of water and contamination on the characteristics of a normal speed quenching oil.

All three phases of cooling occur in the piece at different times. At times, all three phases can be present—which means that some areas are cooled very slowly, while other parts are cooled rapidly. This has the effect of creating thermal gradients on the surface of the part, which can cause distortion (see Fig. 7). The purpose of agitation is to minimize these surface gradients.

Quenching characteristics are influenced significantly by the degree of agitation for a normal speed quench oil under varying degrees of propeller agitation, as shown in Figure 8. It can be seen that increasing the degree of agitation reduces the stability of the vapor phase and increases the maximum rate of cooling. This also minimizes any vapor pockets and ensures that the part has uniform heat transfer across the surface.

However, too much agitation can have the same effect as too little agitation. If the agitation rate is too excessive, then the parts are cooled too rapidly. Large internal thermal gradients occur, and distortion results from the creation of large thermal gradients center-to-surface.

Quenchant. As was discussed previously, there are many types of petroleum-based quenchants. For most gear heat-treating applications, the use of marquenching oils is applied almost exclusively because of the benefits of reducing distortion. However, there are certain applications where cold oils are used, specifically in very large sections, or where press quenching occurs.

Contamination and Oxidation. The condition of the quench oil can also contribute to distortion of gears. Contamination of quenching oils with water must be avoided at all cost. As little as 0.05% of water in quenching oil influences quenching characteristics significantly and may cause soft spots, distortion or cracking (see Fig. 9). At concentrations of 0.5% or more, foaming during quenching is likely, and this can give rise to fires and explosions. Other contaminants, such as hydraulic oil and fire-resistant hydraulic fluids, can also alter the quenching characteristics, resulting in increased distortion and residual stresses.

The oxidation of a quenching oil, measured by the precipitation number or total acid number, is an indication of the level of oxidation of the quenching oil. As the oil oxidizes, it forms organic acids. As shown in Figure 9, the formation of oxidized constituents decreases the stability of the vapor phase and increases the maximum cooling rate. This can increase the risk of distortion and cracking. The use of stable, high quality quench oils will reduce the possibility of this occurring, as will the use of a proactive maintenance program of monthly or quarterly checks for contamination and oxidation.

Racking. Racking of gears is critical in minimizing the distortion. Parts must be located so that the applied agitation will ensure uniform heat transfer on all surfaces of the gear. Uniformity of heat transfer will minimize the formation of thermal gradients on the surface of the parts. The parts must be located so as not to create hot spots from adjacent parts or create mechanical damage from part-to-part interactions.

There are two primary methods for quenching parts. The first method is the use of a press quench. This is a specialized technique involving the physical restraint of distortion-prone parts on close-tolerance fixtures during the quenching operation. It minimizes distortion and movement and is used mainly during the quenching of bearing rings and automotive transmission ring gears. It is a highly manually-intensive operation, as each gear must be removed from the furnace manually and placed on a quench fixture. The press is actuated, and a large flow of quenchant is passed through the fixture. Highly accurate and low distortion parts can be achieved in this manner.

There are several disadvantages to this technique. As indicated above, it is manually intensive, although some robotic applications have been implemented. Because hydraulic fluids are used to actuate the dies, contamination of the quenchant is a problem. This can cause a change in the cooling rate and quenching characteristics, which can cause cracking or fires. If fire-resistant hydraulic fluids are used, then some spots or cracking can occur on the part or the close-tolerance fixture. The quenchant must be routinely checked for contamination and water content. The close-tolerance fixtures used in quench pressing are expensive to manufacture and must be designed for each gear configuration. Should the gear dimensions change, then a new fixture must be designed. Further, the life of the die is finite because of the thermal stresses experienced by the fixture. Distortion and cracking of the fixture can also cause its premature replacement. As a general rule, cold oils are used to harden the parts. This technique is generally limited to flat and symmetrical parts, such as ring gears.

The second method of quenching gears is to place them on a grid or fixture. Many gears can be heat treated in this fashion, greatly improving production rates. However, there are many ways to rack a gear that often depend on the type of furnace, quenchant, and the preference of the metallurgist.

Typically, ring gears are either laid flat on a grid or stacked several high. They can be offset, or stacked directly on top of each other. They are often hung, with supports under the gear.

Either has benefits that depend on the configuration of the gear. If gears are laid flat, they will tend to bend, or "potato-chip," with gears on the bottom and top of the load most prone to this type of distortion. This is due to differential cooling of the gears. In this case, the thermal mass of the grid retains heat, while the upper surface of the gear experiences the full quenching effect of the oil. The upper surface contracts due to thermal contraction, while the lower surface cools slower and does not experience as much thermal contraction. As the upper surface cools to a point where the martensitic transformation occurs, a volume change occurs, placing the upper surface in tension. When the lower surface cools, and its martensitic transformation occurs, a stress reversal places the upper surface in tension and the lower surface in compression. This is complicated by the round shape of the part, so that some areas bow up while other areas bow down, resulting in the "potato chip" shape. The degree of distortion is often dependent on how stiff the section is (polar moment of inertia). This can be overcome by the proper design of racking fixtures.

One thing that is important, when gears are laid flat on a grid, is that the grid itself is flat. Because the material being heat treated is hot and soft, it will conform to the shape of the grid. If the grid is in poor condition and badly warped, then parts laid on it will tend to be warped in a similar fashion. It is very important that proper care be taken with supporting grids, and to discard those grids that are warped or badly cracked. Grids and racks should be routinely stress-relieved to relieve the buildup of quenching stresses over time. This will also extend the life of expensive grids and help minimize cracking.

When parts are hung, the weight of the gear often causes the gear to distort, with the gear becoming the shape of an oval. The degree of ovality often depends on the quality of support and the weight of the part. Smaller parts, fully supported, will tend to distort less. Properly designed supports minimize distortion and provide for uniform heat transfer. One advantage of hanging gears, is that all sides will experience similar heat transfer, assuming no hot spots or proximity of other parts (creating hot oil spots).

Spiral bevel pinion gears are racked vertically. It is preferred that the heavy section is down and is the first to quench. Often, the pinions are offset to allow uniform heat transfer and the minimization of hot spots. Spacers are usually used to maintain the pinions vertically and to prevent movement of the parts.

Modeling of Quenching

Computational fluid dynamics (CFD). Computational Fluid Dynamics (CFD) is a computer model of the flow of fluid. It has been used extensively in the aerospace field to simulate the flow around airframes and structures. This enables the creation of a virtual model to avoid expensive wind tunnel testing and the design and creation of very expensive instrumented wind tunnel models.

CFD is very computationally intense. Previously, it required the use of specialized CRAY supercomputers or networked RISC workstations. However, because of the increase in computing capability and improved algorithms, fairly complex CFD models can now be performed on everyday office computers or laptops. There are three major steps in creating a CFD simulation: preprocessing, solving the mesh, and post-processing.

Preprocessing. Preprocessing is the first step in building and analyzing a flow model. It includes building the model (or importing from a CAD package), applying a mesh, and entering the data. A mesh is created using geometrical shapes, such as cubes, "bricks," or tetrahedral shapes. Data is entered about the fluid, such as viscosity, temperature, inlet velocities, fluid density, etc.

Solving the mesh. After preprocessing, the CFD solver does the calculations and produces the results. The flow characteristics of the mesh are determined by solving the Navier-Stokes equations at each node or corner of the mesh. This is a very computationally intensive step and can consume many thousands of CPU cycles, depending on the complexity of the mesh.

Post-processing. Post-processing is the final step in CFD analysis and involves organization and interpretation of the data and images. An example of the results of a CFD analysis is shown in Figure 10.

The use of CFD allows designing "virtual" quench tanks to examine fluid flow within them and to simulate the interaction of fluid flow with the parts. CFD is commonly used to design quenching systems and to evaluate the effect of changes to the quench tank. It can be used as an aid to understand distortion problems. It can also be used to examine the effect of different racking methods. Capable of looking at the "whole-picture," CFD examines hot spots that occur because of part interactions. Because of this ability to examine the entire quench agitation system, it is extremely useful for modeling racking and thermal gradients in the quenchant.

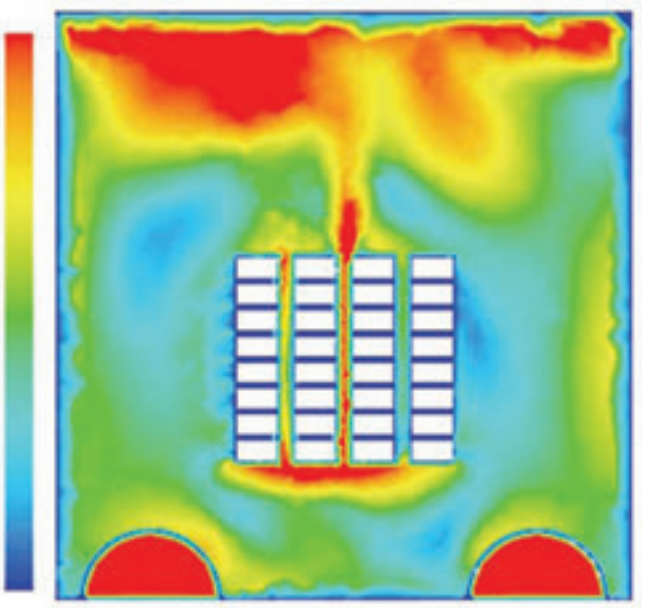

Figure 10—Results of a CFD analysis of a quench tank, showing variations in agitation.

Because of the availability of cost-effective software and improved user interfaces, CFD is a tool that will have increasing applications in solving heat-treating and quenching problems.

Finite element analysis (FEA) of part distortion. Determining the distortion of a part during heat-treating or predicting the microstructure of a part has been a long-held goal of the heat-treating industry. However, this goal has been elusive. Finite element analysis (FEA) has been used extensively to solve structural and performance issues of components. It has only recently been used in predicting part distortion or part microstructure.

To accurately predict distortion or the formation of residual stresses in a part requires an understanding of many factors. These factors include heat transfer, elastic-plastic stress and strain behavior, and microstructure.

Heat transfer is not a steady-state condition. It requires the determination of heat-transfer coefficients as a function of fluid properties, geometry, surface condition, and agitation. It is also time- and location-dependent.

Analyzing elastic-plastic stress and strain behavior requires detailed constitutive models of stress and strain as a function of strain rate, location and temperature.

Knowledge of the diffusion transformations (pearlite and bainite) occurring in the component, as well as the non-diffusion transformations (austenite to martensite transformation, recrystallization, grain growth, etc.) is necessary to accurately predict the microstructure development and its contribution to distortion and residual stresses.

All of these factors (heat transfer, microstructure and elastic-plastic strain) are necessary to effectively model the residual stresses and distortion occurring in a component.

Advantages of FEA modeling of part distortion are many. **These include**:

- Enabling the distortion and residual stresses in a heattreated part to be quantified;
- Examining the effect of part geometry and racking on the development of distortion and residual stresses, includ ing alternative part geometries and racking techniques prior to part creation or heat treatment; and
- Examining causes of failure due to quench cracking or high residual stresses.

Disadvantages of this technique include:

- The technique is computationally intensive. Because of the complexities described above, the learning curve is steep. A skilled engineer is necessary for accurate results.
- Detailed heat transfer, elastic-plastic and microstructure constitutive models must be known. This may require extenive laboratory and field testing for the initial model and verification.
- There is difficulty in measuring and verifying residual stresses. In addition, previous processes play a critical role in the development of distortion and residual stresses. These previous processes are often beyond the scope of cur rent modeling capability.
- There is the limitation of modeling a single part. Since the heat transfer conditions change from part to part depending on racking and agitation, it is very difficult to understand and model an entire quench load.
- The use of finite element modeling of microstructure development and the development of residual stresses and distortion is in its infancy. With the creation and applica tion of better constitutive models, this technique offers great potential in solving many distortion problems before the part enters the furnace.

Conclusion

An effort was made to explain the three phases of quenching and the effect that the quench path has on the development of distortion and residual stresses. The formation of residual stresses from non-heat-treating sources was examined and discussed. The variables affecting the distortion of gears during heat treatment and quenching were illustrated. Finally, methods of characterizing the distortion and residual stresses using computer modeling were described. The limitations of different types of modeling (CFD and FEA) were examined.

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D. Scott MacKenzie is a technical specialist–heat treating products for Houghton International of Valley Forge, PA. His responsibilities include product and customer support for oil and polymer quenchants, salts and other heat treating products. Previously, MacKenzie was an associate technical fellow at Boeing and a manufacturing engineer for heat treating processes and equipment at McDonnell Aircraft Co.

HOT STUFF

HEAT TREATING NEWS

New Basketless Heat Treatment System from Can-Eng

The patent-pending basketless heat treatment systems from Can-Eng are designed for manufacturers of alumimum products requiring process heating or thermal processing.

This system is capable of providing process heating or thermal processing and T4, T5, T6 and T7 thermal processes for sand, permanent mold and thin-walled castings and wrought products.

According to the company's press release, the re-structured airflow throughout the heating chambers facilitates improvements in product thermal profiles.

For more information, contact Can-Eng by telephone at (925) 356-1327 or by e-mail at *tdonofrio@can-eng.com*.

Jore Corp. Orders Surface Combustion Furnace

The Jore Corp. of Ronan, MT, has ordered the Uni-Blue atmosphere furnace from Surface Combustion.

This furnace is the latest extension of the Uni-DRAW and MetaLined batch furnace product lines. The Uni-Blue furnace has an "inside-out" construction that consists of an internal stainless steel casing assembly with an external layer of insulation and light gauge steel/metal covering. According to the company's press release, this design protects the insulation from contaminants which could impregnate the insulation lining of a conventionally designed furnace.

The furnace design provides for a circular wind flow along the inside of the furnace's internal casing. It is electrically heated with sheathed-type heating elements that prevent the direct exposure of the actual heating elements to the furnace atmosphere. Also included in the furnace design are four specially designed water cooled fin tubes for quickly cooling workloads.

Jore Corp. designs, manufactures and markets power tool accessories and hand tools.

New General Manager at Wall Colmonoy

Donald C. Hainley has been named general manager of Wall Colmonoy Corp.'s Dayton business unit.

According to the company's press release, he will oversee thermal spraying, furnace brazing and thermal processing of all types of materials.

Hainley has 20 years' experience in heat transfer technology and product development for the aerospace industry. His most recent position was technical director for an aerospace component manufacturer.

Donald C. Hainley

Wall Colmonoy manufactures metal coating and joining products and offers alloy manufacturing and contract services in prototype development, overhaul, brazing, heat treating and precision machining.

SECO/WARWICK Furnaces Installed Worldwide

SECO/WARWICK delivered a vacuum furnace with a convection heating and 10-bar gas quenching system to the Bodycote Heat Treatment Centre at Woodford, Cheshire,U.K.

According to the company's press release, this furnace is capable of hardening, vacuum carburizing, annealing and tempering on a variety of loads.

This equipment is designed for the needs of commercial heat treaters. Convection heating enables a hardening and multi-stage tempering of the load in a single furnace cycle.

Bodycote's Woodford facility was the first heat treatment plant in the U.K. to specifically service the aerospace industry. Last year, it was the first sub-contract heat treatment service in Europe to gain NADCAP approval.

In recent weeks, several other SECO/WARWICK furnaces have been installed at international companies. Cooper Power Systems has purchased a new transducer core annealing furnace system for its facility in Jalisco, Mexico. A semi-continuous, three chamber, electrically heated CuproBraze furnace system will be the seventh CuproBraze system installed at Suomen Jaahdytintehdas Oy, a Finnish-based radiator manufacturer.

Lastly, Metals Technology Corp. has purchased the 15-bar Universal High Pressure Quench Vacuum Furnace for its heat treat facility in Carol Stream, IL.

Surface Combustion and Air Products Introduce Joint Marketing Strategy

Surface Combustion Inc. and Air Products & Chemicals have entered into an agreement in which both companies will jointly market their product lines to the metals processing industry.

Industrial gases, services, and atmosphere generating equipment are among the technologies the two companies will promote.

Surface Combustion of Maumee, OH, manufactures thermal systems in the metals processing and heat treating industries.

Air Products & Chemicals supplies industrial gases to customers who use Surface Combustion's PUREFIRE atmosphere systems.

"Many times, our customers require a combination of industrial gases and generated atmosphere for their specific metallurgic application for an economic reason," says Daniel E. Goodman, Surface Combustion's vice president of sales, in the company's press release.

Brown Named Inductoheat's Division President

Douglas Brown

Douglas R. Brown was named president of the forging division at Inductoheat's Madison Heights, MI, office.

According to the company's press release, his new responsibilities include the global sales, marketing and manufacturing of induction heating for forging products, including the recently released InductoForge line of billet heaters.

Brown has worked in the induction heating industry for the past 25 years and specialized in forging for the last 15 years. Most recently, he served as director of forging for Inductotherm's North American operation as well as president of the Alpha 1 Induction Service Center.

New Sales Rep at Vacuum Furnace

Stanley Zinn was hired as the New York sales rep for Vacuum Furnaces Corp. of Souderton, PA.

Zinn is the owner of Fettotherm Inc., a Rochester-based firm that specializes in providing process heat treating. With this new contract, Zinn will cover the entire state with the exception of the New York City metropolitan area.

Stanley Zinn

According to the company's press release, Zinn has been involved in the thermal processing industry for the past 50 years. He holds memberships in the American Society of Engineers, the Society of Manufacturing Engineers (SME), and he is a founding member of the Heat Treat Institute.

Vacuum Furnace Sells Furnace to Bio-Vac

Vacuum Furnace Corp. sold a vacuum furnace to Bio-Vac Corp. for its Southfield, MI, orthopedic coatings plant. The new horizontal two-bar external quenching system will join four other VFS furnaces currently in operation at this plant, plus two at the Bio-Vic facility in Valencia, Spain.

According to the company's press release, the Model HEQ03836-2 minimizes oxidation and enhances adhesion and luster of the coating. The furnace has a work zone of 24" wide by 24" high x 36" deep and a graphite-insulated hot zone and GraForm curved graphite heating elements that can be used in their proprietary coating process for orthopedic implants. In addition, the furnace's programmer/controller contains an interactive touch-screen workstation.

Vacuum Furnace designs and manufactures high performance vacuum furnaces for thermal processing applications in the metal treating and brazing technologies industries.

Executive Appointments at Watlow

Watlow, a designer and manufacturer of heaters, controllers and temperature sensors, has named Harvey Feldstein product manager for the company's swagged/non-swagged (SNS) product line. He was most previously employed at Cooper Bussmann as senior product manager responsible for developing annual product line business plans, competitive product/market positions and distribution channels.

Harvey Feldstein

Steve Rhoads was promoted to director of operations. Among his new responsibilities are swagged/non-swagged operations as well as overall facilities management.

Rhoads has been with the company for the past 28 years, most recently as a senior operations manager.

Fran Fritz was hired as European marketing manager. Prior to joining Watlow, he was employed by Johnson Controls of Milwaukee, WI, as divisional products manager where he worked in both the United States and Germany.

Heatbath Acquires the Assets of Chemtech Finishing

Heatbath Corp. of Springfield, MA, has acquired the assets of Chemtech Finishing Systems.

According to a letter from Chemtech's president, key personnel with Chemtech will be retained, and production to their customers will not be interrupted due to their distribution through Heatbath's facilities.

Heatbath Corp. and its subsidiary Park Metallurgical manufacture heat treating salts and quenchants as well as metal finishing products.

New contact information for Chemtech orders and service are:

Phone: (413) 452-2000

Fax: (413) 543-2378

Latest Nitrex Installations and New Japanese Distributorship

Nitrex completed a turnkey installation of two NX-1025 systems at DaimlerChrysler do Brasil for treating automotive gears.

According to the company's press release, the furnace has a work zone diameter and height of 1,000 mm x 2,500 mm (40"x 98"), a 5,000 kg load capacity, and are outfitted with two closed-loop cooling systems as well as a neutralizing unit to eliminate effluent gases.

Earlier, Hitachi Canadian Industries had started up a top-loading 2,000 kg load capacity, NX-820 system in Saskatoon, Saskatchewan for nitriding stainless steel generator components used in the power generation industries.

Finally, Nitrex Metal has contracted Correns Corp. to supply the complete line of Nitreg® nitriding and nitrocarburizing systems to the Japanese metal processing industry.

Alfe Heat Treating Celebrates 25th Anniversary

Alfe Heat Treating recently celebrated its 25th anniversary.

The company currently has nine facilities throughout the country.

Alfe Heat Treating is owned by Alfe Corp.

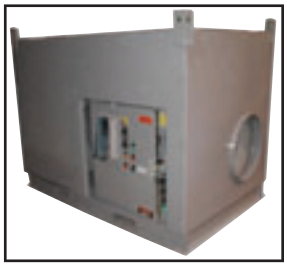
Ipsen Ships Furnace Line to Taiwan

The Ipsen I/O 3000 internal quench batch furnace line has been sold and shipped to the Shenli heat treating facility in Taiwan to heat treat various components for automotive and tool and die manufacturers.

According to the company's press release, this furnace has a rigid housing, durable door assembly and ceramic muffle providing tight atmosphere and temperature uniformity. In addition, both atmosphere furnaces operate electrically with an integral oil quench, two endothermic generators with air-cooled heat exchanges and two directional load cars for loading and unloading parts.

Ipsen International of Rockford, IL, manufactures atmosphere and vacuum heat treating furnaces and systems, process controls, automation and supervisory technology.

New Temperature Control Systems from Chromalox



The new HACS system from Chromalox provides temperature control and air handling capabilities for any large capacity temporary heating application.

According to the company's press release, the unit does not produce emissions and is designed for the maximum combination of flow, control, construction and monitoring options.

Air handling units can be designed up to 150 kW and 7,000 SCM air at 5" WG.

For more information, contact Chromalox of Pittsburgh, PA, by telephone at (800) 443-2640 or on the Internet at www.chromalox.com.

***Send Your News Items to*:**

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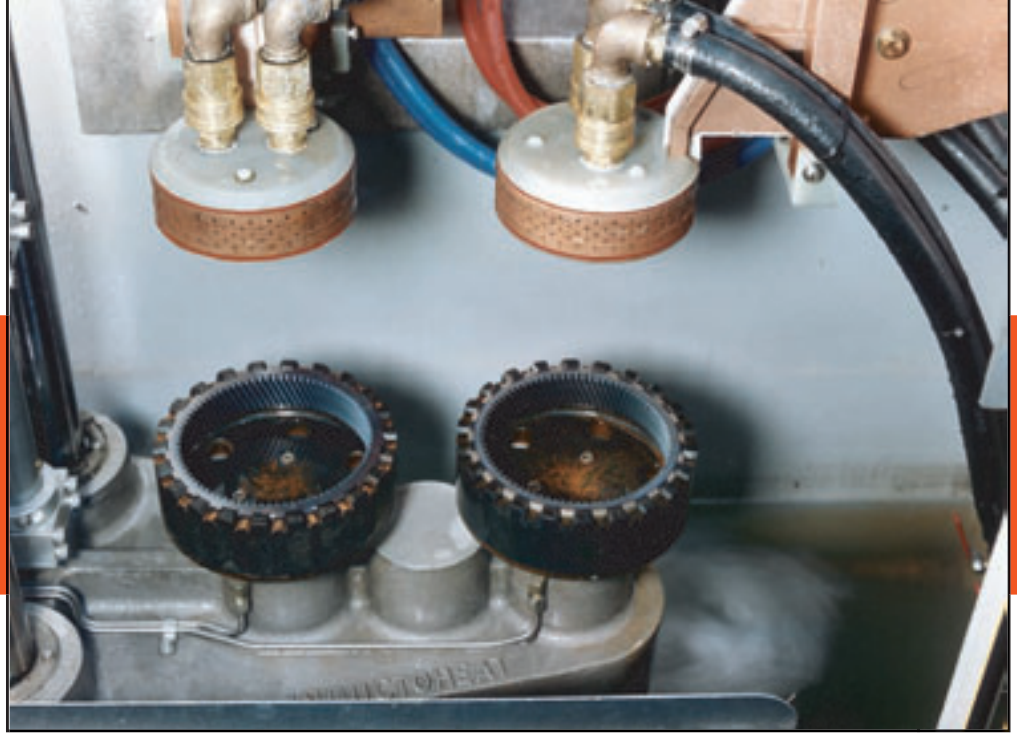


THE

Ring gears from Inductoheat.

Gear Up for Induction Hardening

— Daniel J. Williams

Daniel J. Williams
is Managing Director, Heat Treat —China at Inductoheat Inc. of Madison Heights, MI. He has completed advanced study in metallurgy and thermodynamics and holds an MBA. Williams is the author of numerous articles on induction heating, quenching, process controls and quality systems.

Management Summary

Part one of this series on induction hardening of gears, originally printed in the March/April 1998 issue of *Gear Technology*, provided a step-by-step guide to assist readers in specifying induction hardening equipment. Part two covers machine preventative maintenance and modification of machinery to induction harden different gears.

So, you have purchased your induction heat treating system. This machinery is an integral part of your production line and needs to run consistently around the clock. What can you do to assure that your induction hardener is able to run three shifts a day, seven days a week?

Along with preventative maintenance, which should be performed by your induction equipment supplier annually, the checklist below should be followed. Routine maintenance is the best way to assure that the machine produces quality parts and remains in good working order. These procedures should be performed daily:

1. Inspect a cross-section of a gear coming off the induction hardener by performing a destructive test followed by an acid etch. Examine for pattern location and hardness Once a week, a sample should be prepared, mounted and inspected for desirable microstructure. If parts are prone to cracking problems, magnetic particle inspection should be utilized until the root cause of the problem can be determined and eliminated. If the possibility of cracking persists, non-destructive eddy current inspection can be used for 100% inspection and automatic sorting of cracked parts. Inspection of the part assures its quality and is also used to confirm that machine motions are operating within specifications. Maintenance of the guide shafts and ways is confirmed with precise accurate motion.

2. Inspect all percent meters on the induction power supply inverter to assure consistency with expectations.

3. Inspect the quench water additive to assure desired ratio is consistent with expectations and recommendations. Polymer quenchant manufacturers should be consulted for each application to assure compatibility with other fluids that may be introduced.

HEAT GOES ON

4. Check the quench temperature. If it's too cold, the part will crack. With a quenchant that's too warm, the required level of hardness will not be obtained.

5. Assure that the number of kilowatt-seconds is consistent with expectations.

6. Inspect the quench filter and clean or replace as necessary. If the filter is plugged, quench flow will be restricted and proper hardening will not take place. On newer systems, pressure gauges across the filter should be checked. Older systems require that the canister be manually opened and visually inspected.

7. Observe several machine cycles to assure that the part is properly rotating.

8. Inspect the coil and bus connections for debris, and ensure the connections are tight. Field service technicians frequently are called to plants when arcing occurs, only to discover that the coil and bus connections are loose.

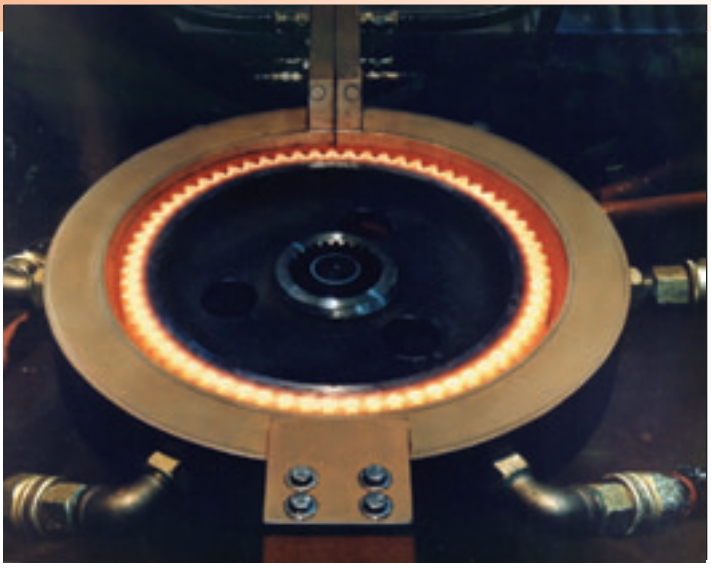
9. Assure that the isolation transformer connections are tight.

10. Check quench holes for obstruction and clean as needed. The quench ring often (unfortunately) acts as a quench filter and collects particles (scale), which eventually cause blockages in quench flow. This reduces the cooling effect of the quenchant, leading to inconsistent results.

11. Assure that the inductor coil is properly located with respect to the part. Check for concentricity between the coil and part in the known heat treat position.

Every six months, drain and clean the quench tank, then replace the fluid. Clean or replace all filters and check quench holes for obstructions. Then, inspect coil for cracking around quench holes.

Be sure to also check for loose hoses internal to the power supply.



Gears in the midst of one of Inductoheat's hardening processes.

Machine Modification to Handle Various Gears

As a follow-up to these points, this article will discuss ways to modify induction hardening machinery to handle additional gear applications.

Can I use my induction system to process a different gear?

Gear #123 is being successfully processed on your induction hardening system. However, your company has just received a large contract to manufacture gear #789. Part prints show that gear #789 will require induction hardening. Rather than immediately deciding that new equipment is the order of the day, it may be possible to retool an existing system. The following factors must be considered:

Capacity. Is there open capacity on current induction machinery? If your answer is yes, continue considering a retool. If not, purchasing an additional piece of equipment may be your only option.

Machine's frequency. Part prints will indicate the case depth required for gear #789. Frequency selection is very important to obtain specified results.

Too low of a frequency will leave the tooth tips unheated. On the other hand, heating with too high a frequency will not heat the root area and will overheat the tips (see Fig. 1).

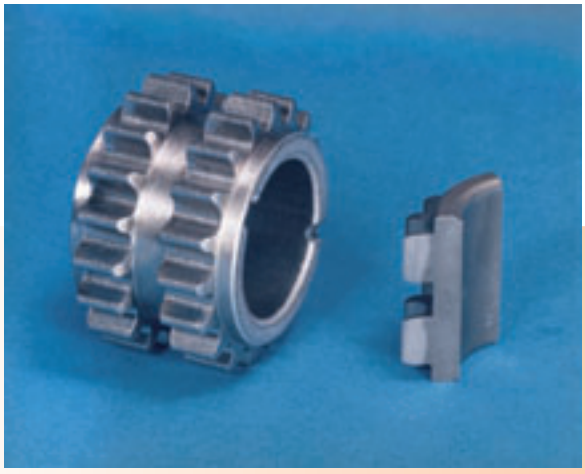
Even if the frequency does not match that used on the current equipment, it may still be functional by adding 25–50% to the "heat on" interval. If the frequency is far out of range, you may consider purchasing a more appropriate power supply and having it installed in the existing machine platform.

Table 1—Examination of Power Supply (Frequency and Power).

	Analysis Available vs. Required	Action
Frequency	The available frequency is greater than or equal to the required power supply	Use existing power supply
Frequency	The available frequency is too low	Buy new power supply
Power	The available power supply is greater than or equal to the required power supply	Use existing power supply
Power	The available power is too low	Buy new power supply

Power. Power determination is calculated based on five major factors: prior microstructure of the part; material; case depth required; diametral pitch; and surface area to be hardened. Further experiments establish power levels for a thermally hardenable material with three different microstructures (annealed, normalized, and quenched and drawn). If the required power is equal to or less than that currently owned, move ahead. If not, consider buying a new, larger power supply to be installed in the current machine platform.

Part size. Will gear #789 fit into the machine? The existing induction equipment does have certain space limitations. The maximum diameter of gear #789 (or any gear) cannot exceed center-to-center machine constraints (approximately 10" in this example).



Sprocket gears are among those most suitable for induction hardening.

Both single- and dual-spindle machines offer options. If the major diameter of gear #789 exceeds 10" on a dual-spindle machine, a simple solution is to utilize only one spindle to allow for more space. In other words, a dual-spindle machine is modified to become a single-spindle. If gear #789 does not exceed the 10" maximum, a dual-spindle machine can continue to operate as a dual-spindle.

Tooling. If your examination determines that this job can be processed on existing equipment (i.e., open capacity exists and the power and frequency are acceptable), then retooling the machine is the next step. An important tip: Locator tooling is best purchased from the same company designing and building the inductor coil. Proper locator tooling is essential to minimizing or eliminating part distortion.

Perishable tooling includes locator tooling. Part touch tooling, as the name implies, touches the part. It is designed by looking for datum surfaces that are repeatable within 1/10 the tolerance of the heat treat specifications. The lateral position and height must also be established in the case of vertical machines. Concentricity of the gear within the coil must also be examined.

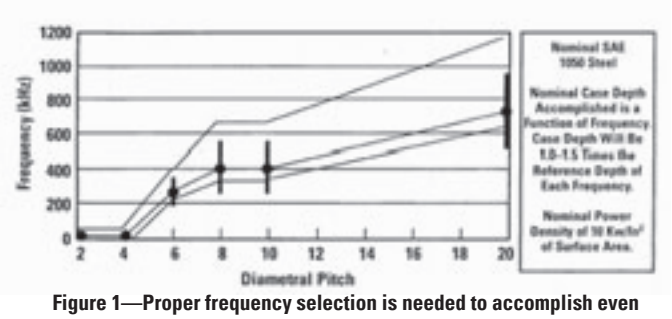


Figure 1—Proper frequency selection is needed to accomplish even heating across the part. It may be possible to have a new power supply installed in the current platform.

Ideally, tooling will be non-ferrous to avoid corrosion or inadvertent heating by the magnetic field of the inductors. Mild steel can be used in cases where the locator tooling is sufficiently spaced from the inductor coil. Zinc dichromate or electroless nickel coating will enable mild steel to weather the quenchant.

Inductor. Inductor coils are application-specific and, therefore, gear #789—and most others—will require a new coil. An inductor coil will be designed nominally with an air gap that is no greater than 1.50 times the reference depth of heating for the given frequency. Quench holes will be selected to obtain 5–10% coverage on the coil heating face. Locator tooling and inductor coils are best developed by your induction equipment supplier before committing to a rebuild, a new power supply or even a new machine. Advance process development is completed to assure that metallurgical results obtained are satisfactory and acceptable. Quite often, results are not as hoped and part material, heat treat specifications and even product design may require modification. Locator tooling, inductors and process development are completed to establish satisfactory metallurgical results.

Buying Locator Tooling and Inductors

Although development of new part locator tooling may seem an easy task to a team of experienced engineers, it is actually best designed and built by an induction equipment supplier. Locator tooling is imperative to a successful induction process, as it establishes the correct relative location between the part and tool.

Locator tooling can also affect distortion of the part and should be designed in a way that minimizes distortion of the gear itself (i.e. taper and runout). Proper or improper design can prevent or add to distortion. Furthermore, locator tooling must be validated to assure that the part is not being distorted.

Choosing a material able to survive the induction environment is an important part of the design process. The selected material must be:

a) Able to withstand the proximity to the magnetic field and not intersect lines of flux;

b) Impervious and not affected by repeat exposure to quench; and

c) Self-cleaning.

Unless the gear in question is already in production and a suitable coil has been designed and built, a metallurgical laboratory is needed to test the coil and prove the process.

Inductor coil designs are difficult to predict. A design-build-develop (DBD) program, completed by an induction equipment supplier with an in-house metallurgical laboratory and a full-time metallurgist, is the best source for obtaining the proper coil. Repeated lab testing may reveal that the coil requires several slight modifications (e.g., air gaps and size specifications).

A quench barrel may be required in some cases. For instance, when the outer diameter of the gear requires quenching while the inner diameter is heated. Process development is required to assess whether a quench barrel is required.

Likewise, use of magnetic flux concentrators can only be confirmed via prior development.

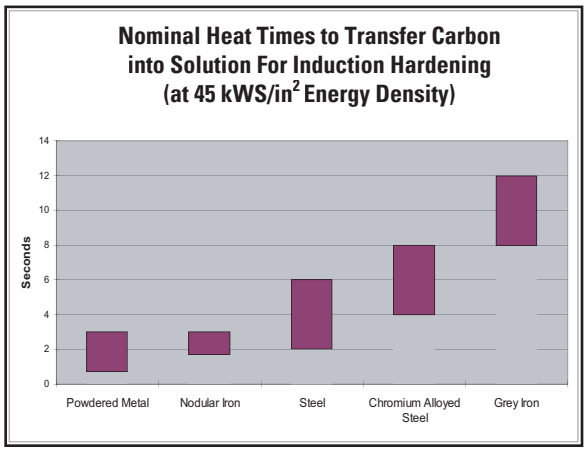


Figure 2—Typical power-on times for single-shot heating generally range between 2–20 seconds. (For scan heating, assume 0.25–2.0" per second.)

The equipment supplier's lab source will need guidance with respect to accomplishing desired results within the power supply size and power supply frequency constraints of the existing machine. For example, avoid allowing your induction equipment supplier's met lab to develop a gear hardening process at 200 kHz, if you have 30 kHz available. (Or until they prove that the 30 kHz just won't do the job.)

Quench barrel. A quench barrel may be needed for quenching out of position.

Finally, after obtaining satisfactory metallurgical results, the supplier's lab documentation is needed to confirm plans for implementation at your existing facilities. Get a quotation from your supplier for production-worthy tooling and implementation. This would include inductor coils, quench rings, locator tooling and any necessary machine modifications for adapters for the existing equipment to accept the new tooling and process. This would be an ideal time to consider replacement of the induction power unit with a variable frequency induction heating power supply, which enables future flexibility of the existing equipment. Field service may also be specified to assist with initial setup and debugging of the gear heat treat process.

Competitive pressure forces management to consider how to make more gears, of the same and of different types, on the same or lesser equipment, with no or minimal capital outlay. Careful consideration needs to be given to existing equipment's capability and flexibility before investing more cash into production equipment.

gear data EXCHANGE

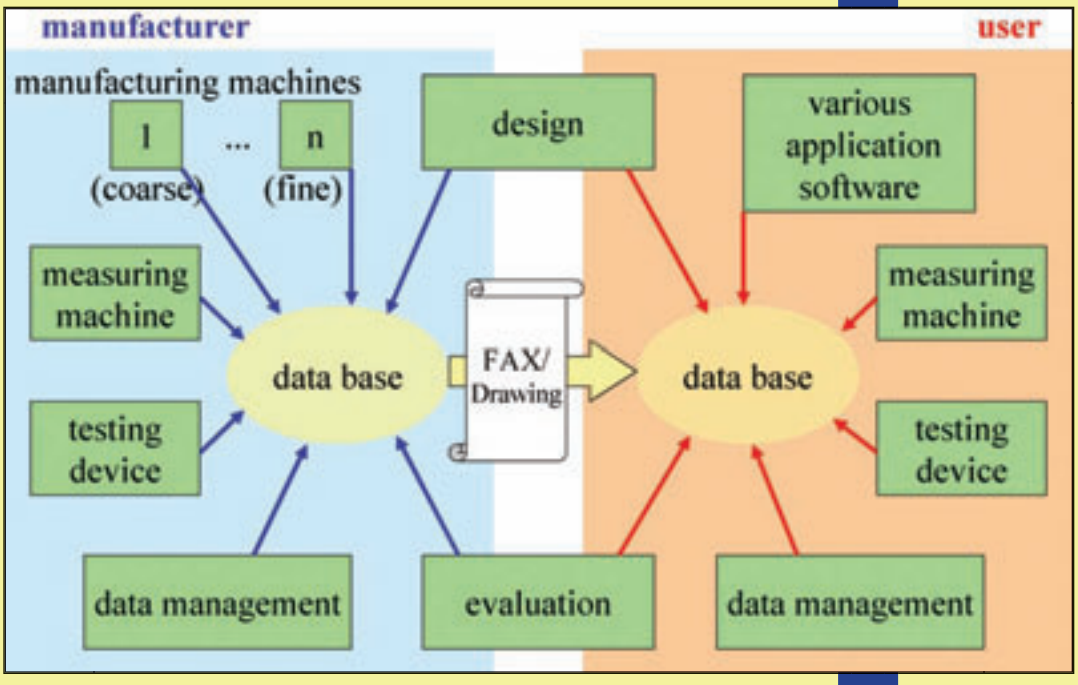


Figure 1—Data exchange between different companies.

Management Summary

The exchange of gear data between design, manufacturing and quality inspection operations is a unique, or individual, solution in many companies, with no conformance between suppliers or customers. So manifold errors or misunderstandings can result when the companies send to each other data sheets printed on paper—especially when they're faxed or when they're photocopies of photocopies of photocopies. Errors or misunderstandings can also result when the sheets are transmitted electronically using nonstandardized file formats.

To improve this situation, the Association of German Engineers (VDI) created a data exchange format for gears in conjunction with the Association for Electrical, Electronic & Information Technologies (VDE). This format allows for the electronic exchange of all geometric parameters for cylindrical gears.

format

by
Günther Gravel and Anke Günther

Introduction

VDI/VDE Technical Committee 3.61 "Measurements of gears and gearboxes" has defined a data exchange format for gears. This format appeared in Germany in September 2003 in a new guideline, supported by VDI and titled "Exchanging format for gearing data—Gear Data Exchange Format (GDE)." It contained the definition of a data format suitable for exchanging electronically all geometric parameters for cylindrical gears—including their modifications and tolerances—between design, manufacturing and quality inspection personnel. This format is based on Extensible Markup Language (XML). It can easily be integrated into most database applications and Internet environments.

The advantages of a coordinated, uniform (standardized) data exchange format are obvious. Additionally, the VDI committee constantly works on a systematic extension of this format, including with regard to gear cutting tools and other processes.

This paper gives, on the one hand, an overview of the GDE format and its specific content and provides a description of a practical application of this new development, which opens up new possibilities. Moreover, it reflects the format's current state of development and its new trends.

Motives and State of the Art

Information about a product today usually consists of large and complex amounts of data which describe the manufacturing process, machines, instruments, semi-finished products and materials involved, as well as the environmental conditions. Modern, highly specialized multi-step manufacturing processes, quality tests and statistical evaluations generally are based on different systems and data processing structures. Data exchange among the companies involved usually takes place through posting of drawings, by electronic mailing of scanned files, or via fax (see Fig. 1).

The data are then entered into a database system, usually by hand. Data transmission problems (arising, for example, in fax communication or during the scanning of model documents), errors made during entry of the data, and a limited readability or incorrect interpretation of drawings may lead to considerable misunderstandings and unnecessary delays.

Inside the companies, the situation is not much better. Data exchange between the individual systems usually takes place via specially developed, expensive conversion programs or, likewise, by time-consuming manual data transmission susceptible to errors. Progressive enterprises have a central data administration system at their disposal. They require defined interfaces through which the interconnected instruments communicate.

Requirements for a Uniform Data Format

With these problems in mind, VDI/VDE Technical Committee 3.61 "Measurement of gears and gearboxes" has specified a data exchange format for gears (GDE: Gear Data Exchange) which allows all data arising in the process of design, manufacture and quality testing to be described and exchanged. Several manufacturers of gears and measuring instruments, as well as members of research institutes, are cooperating to define the contents.

Dr. Günther Gravel

is a professor for production engineering at the Hamburg University of Applied Sciences, located in Hamburg, Germany. He is also head of the university's Laboratory of Production Engineering. A mechanical engineer, he has 18 years' experience in measuring gears, especially in high accuracy measurement, in software development and in analysis and correction of deviations. He is also chairman of the VDI committee that creates VDI guidelines for measuring gears and gearboxes.

Anke Günther

is a scientific assistant with the Bremen Institute of Industrial Technology and Applied Work Science (BIBA), a part of the University of Bremen, located in Bremen, Germany. An electrical engineer, she works in the institute's MAQ department (metrology, automation and quality science) developing software for measuring bevel gears. Günther is a member of several DIN and VDI work groups that develop guidelines for gear tolerancing and coordinate measurement, including the group developing VDI's gear data exchange format.

Figure 2—Representation of a GDE file in Internet Explorer.

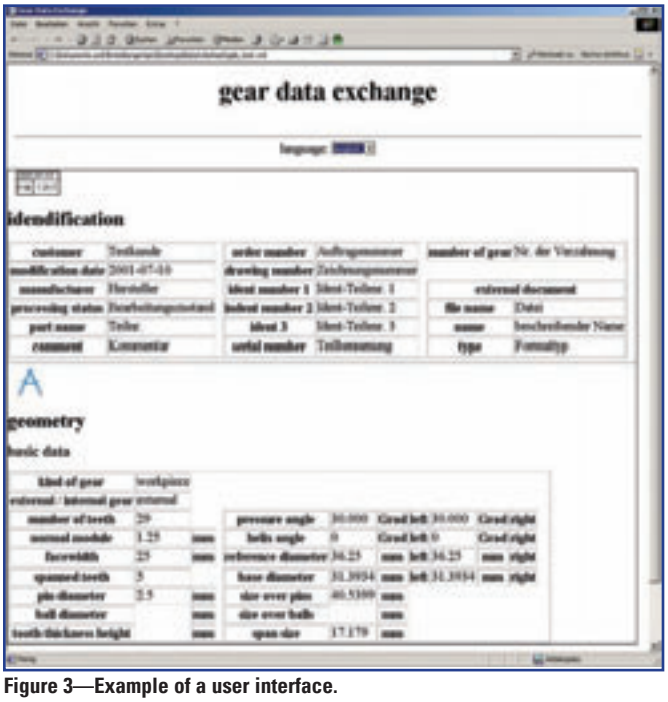


Figure 3—Example of a user interface.

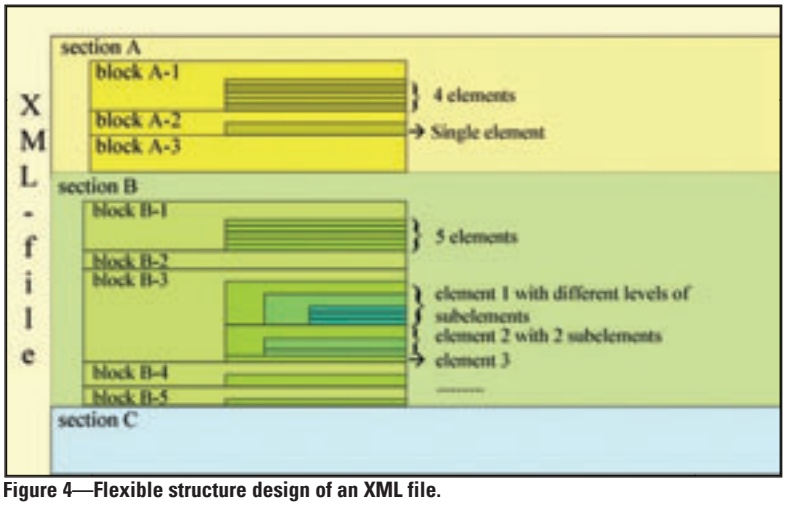


Figure 4—Flexible structure design of an XML file.

Likewise, the AGMA Data Exchange Protocol Committee is developing an information sheet on a system for digital storage and retrieval of gear metrology and related data for cylindrical gears. The committee is scheduled to publish its AGMA information sheet by the end of 2005. During its work, the committee reviewed the guideline on the VDI/VDE gear data exchange format. The AGMA format and its content are expected to undergo a formal ballot in which the committee members may comment.

In the VDI/VDE effort, broad agreement and acceptance are ensured by discussions among manufacturers of machine tools and cutting tools. The envisaged data format makes possible universal, rapid and—above all—safe communication between the different systems and databases. In addition, the format has a clear and extensible structure and may be mapped with readable ASCII characters. All users must, moreover, be given the possibility of representing their individual data in this format (Ref. 1).

When a new data format is designed, the essential questions are which structure is to be used for data description and which tools will make data processing possible. It is desirable and useful to fall back on established products which are widely used. They allow a wide spectrum of users to integrate the data format into their specific applications, with as little effort and outlay as possible. A modern data exchange format which meets these requirements and which is, moreover, suitable for Internet applications is XML.

Characteristics and Advantages of XML

The data format is based on the XML format, a format standardized throughout the world, which is especially well suited for Internet and database interfacing. XML has been developed on the basis of the application of, and the experience gained with, SGML (Standard Generalized Markup Language) and HTML (Hypertext Markup Language). Moreover, XML is a data-oriented format

and thus well suited for the description of complex data types. The structured data are filed as text files.

In addition to being easily readable (clearly structured ASCII text), the format has a structure which makes possible both flexible extension and easy description of user-specific sections. Integration into a database is usually easy, and utilization does not require a license. Meanwhile, it is yet another advantage that all operating systems commonly used are equipped with standard software tools with which the format can be read and processed (see Fig. 2).

A large number of suitable programs is available with which attractive data sheets or user interfaces can be designed to simplify data input. These aids make the direct processing of ASCII files superfluous. Figure 3 shows an example of an interface for data input.

The outward form of such an input interface can be individually designed by every user.

XML permits nesting of the data to any depth. The number of single elements per nesting level can be freely defined. Lacking elements and blank elements are possible (see Fig. 4).

The XML specification allows for separate management of the data structure definition and of the data set proper. The situation in practice will be as follows: VDI makes available a "complete" structure file (gde.dtd) without any data. This file is the definition file for all "valid" GDE data records. Taking this definition file as a basis, every user may design suitable GDE files which he may require to describe his data (see Fig. 5).

If the structure file is extended (by VDI or by user supplements), the data records of a previous structure file will be "valid" even at a later date.

Integration of the Exchange Formats

Another data model for the exchange of gear data is at present being developed, with the emphasis placed on the design of gearings (Ref. 2). This model is based on the CAD interface Step, and the aim is complete mapping of a gearing. Many modern programs for computation, simulation and construction are to be interconnected with its aid. The aspect of describing the gearings in relation to the shaft, which is also highly fascinating with regard to manufacture, inevitably leads to a highly complex data structure.

The GDE format, however, is to make fast and simple data exchange possible and is to support gear manufacture in particular. As the topics covered by the two formats supplement each other very well, there is close cooperation between the bodies concerned (see Fig. 6). After both formats have been introduced and established in the form of directives, it appears reasonable to combine in an ISO standard in the long run.

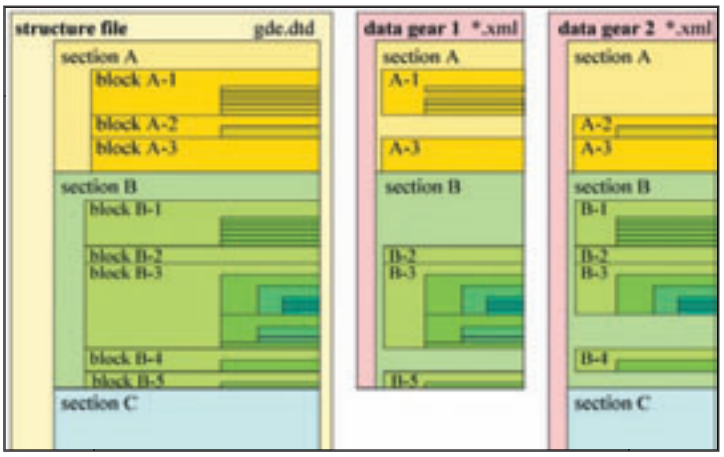


Figure 5—Separation of structure and data.

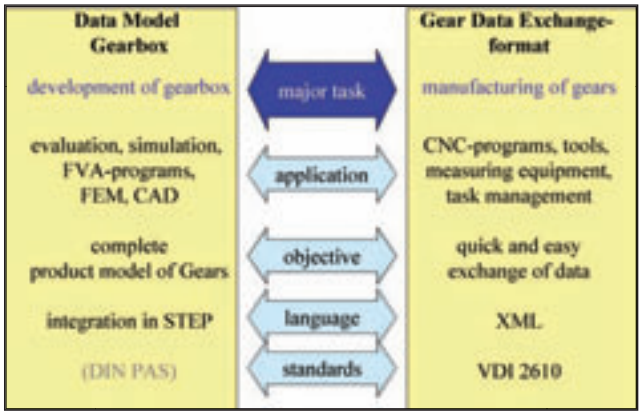


Figure 6—Integration of the data formats.

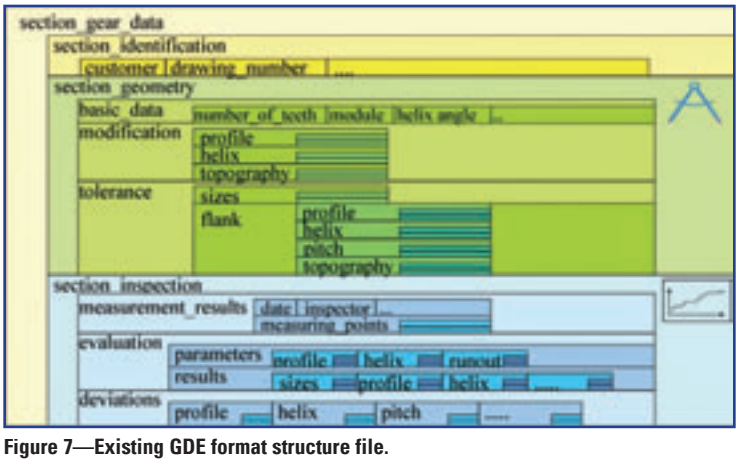


Figure 7—Existing GDE format structure file.

Structure

GDE currently covers all geometric characteristics of cylindrical gears,

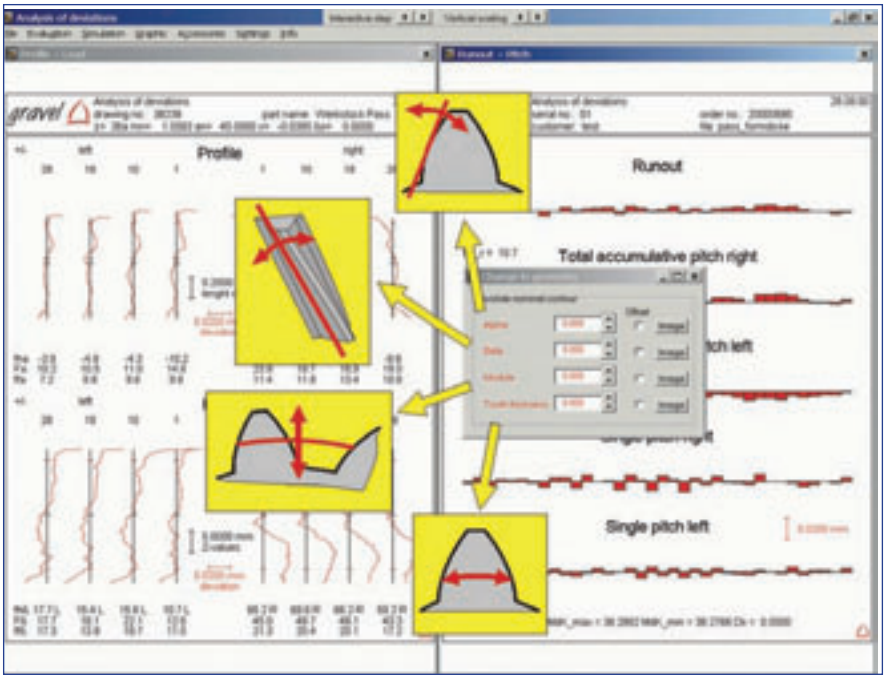


Figure 8—Program for the analysis of gear deviations.

including their modifications and tolerances. A large part of the measurement results has also been integrated (see Fig. 7). Still under preparation are sections describing bevel gears and splines and a section covering measurement and evaluation instructions for the automatic programming of gear measuring instruments. It has been planned to continue extending the areas already defined, in compliance with the users' requests, an essential prerequisite for this being compatibility, because constant adapting of existing interface programs must be avoided.

The identifiers of the individual keywords are stated in English. The directive will make available for the structure file a table with the German translations of the terms used. VDI/VDE Technical Committee 3.61 will be responsible for extensions of the GDE format in the future. Supplements proposed will be discussed at the committee meetings held every six months, and the programs will then be updated accordingly. Version numbers will be assigned to the different stages of development to ease management. Upward compatibility is to be guaranteed. VDI Guideline 2610 is currently available as a white paper (Ref. 3).

Example of Application

The following example demonstrates the possibilities and perspectives offered by a generally valid exchange format. An evaluation program for the analysis of errors arising in manufacture accesses the data of a measuring instrument and represents them (see Fig. 8). The effects of typical errors can then be simulated interactively and the real errors corrected. The correction values can be used in manufacture immediately and without further calculation. This powerful program consists of many tools for easy graphic comparision of measurements and for detection of systematic errors. Wearing of tools, hardening deformation or trends in production can be found with a click. The analysis program is now available with the GDE interface, so the program can be used with every gear measuring machine that supports the GDE format.

Summary

In summary, the utilization of a uniform exchange format allows software to be developed—independent of the measuring instrument and its interfaces—that can later be run to analyze and optimize production. The GDE interface will make additional developments possible in the future. Until now, these developments have not been feasible for purely economic reasons.

An earlier version of this paper was presented at two conferences: the International Conference on Gears, held March 13–15, 2002, in Munich, Germany, and Gear Measurement, held June 4–5, 2002, in Mannheim, Germany. The first presentation was published in VDI Report 1665, the conference's proceedings, by VDI Verlag GmbH. The second was published in VDI Report 1673. At both conferences, the version was written by Anke Günther, Frank Härtig and Günther Gravel. Härtig's contribution was a planned application of the gear data exchange format, but the application wasn't carried out as expected, so his contribution wasn't considered in the revised paper published here. This paper is republished with VDI's permission.

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2. Höhn, B.-R., K. Steingröver and A. Dyla. "Integrierte Entwicklung von Getrieben: Praxisanwendung und Visionen," VDI Report 1569, 2000, pp. 115–135.

3. Verein Deutscher Ingenieure/ Verband Der Elektrotechnik Elektronik Informationstechnik, VDI/VDE Guideline 2610, *Gear Data Exchange Format (GDE)*, September 2003.

Hannover Fair Welcomes World Leaders, Global Gear Manufacturers

International visitors discuss the latest technology.

Thousands walk the halls at Hannover Fair.

During April 11–15, Hannover, Germany, will host the largest international contingent of industrial automation technology professionals. Hannover Fair 2005 encompasses 11 trade fairs within a single venue. The Hannover Convention Center will welcome participants from 60 countries to the following pavilions:

- INTERKAMA—process automation
- Factory automation
- Motion, drive and automation
- Digital factory
- MicroTechnology
- Research & Technology
- Energy
- ComVac—compressed air and vacuum technology
- Surface Technology plus Powder Coating Europe
- Subcontracting
- Industrial Services & Repair

Professionals in all of these disciplines will have the opportunity to hear German Chancellor Gerhard Schröder and Russian President Vladimir Putin officially open the exposition on April 10. The following day, the two will lead the Russian-German Business Symposium in Hall 13.

Gear buyers worldwide can browse products from ATA Gears, Bonfiglioli Riduttori, Brevini, Davall Gear, Flender, Great Taiwan Gear, Hansen Transmissions, IMS Gear, Metso Drives, Mijno Precision Gearing, Ronson Gears, SEW Eurodrive, Textron Power Transmission and many more.

Mijno Precision Gearing is planning on displaying two product lines at Hannover Fair 2005. The precision rack and pinion product line, which is now operating at quality levels up to AGMA 12, and low backlash planetary gearheads that can bolt onto servomotors, will occupy most of their programming.

"This show is always one of our better forums as we sell worldwide. Hannover always has a significant European presence, but there are a great deal of Asian and South American customers as well," says Tom Provencher, Mijno's director of sales and marketing.

Leading power transmission manufacturers include Animatics, Dana Corp. Formsprag Clutch, Marland Clutch and Pacific Bearing. The American Gear Manufacturers Association will have a booth to promote the activities of the U.S. gear market.

For more information:
Hannover Messe
Messengelände
D-30521 Hannover, Germany
Telephone: +(49) 511-89-31146
Fax: +(49) 511-89-31149
Internet: *www.hannovermesse.de*

SAE Marks 100th Anniversary at the 2005 Congress

The Society of Automotive Engineers will be celebrating its 100th anniverseary at the SAE 2005 World Congress and Exhibition, which will be held April 11-14 at Detroit's Cobo Center. The annual event features a trade show with more than 500 auto industry manufacturers and suppliers, as well as a technical congress featuring presentations in more than 275 individual sessions.

Both the expo and the congress are organized into technology pavilions:

- **Electronics Technology**
- **Environment/Emissions**
- **High Performance**
- **Materials**
- **Safety/Testing**
- **Propulsion/Powertrain**

Gear industry exhibitors will include major OEM manufacturers, such as Getrag, Aisin Drivetrain and the transmission divisions of many leading automobile manufacturers. Other gear manufacturing companies exhibiting include Flywheel Ring Gears Pvt. Ltd., Gajra Gears Pvt. Ltd., GNA Axles Ltd., Graziano Trasmissioni SpA, Hi-Tech Gears Ltd., Hota Industrial Mfg. Co. Ltd., Jiangxi Jiangling Gear Co. Ltd., mG miniGears and Suhner Manufacturing.

"Our company decided to exhibit at the congress because we are looking to expand our business further into automotive," says Arthur Pantelides, general manager of mG miniGears North America, located in Virginia Beach, VA. "Currently, we are supplying Tier 1 companies with precision gears and mechanisms. We feel we can expand on our unique capabilities of producing precision powdered metal gears, cut metal gears as well as assemblies, and provide customers with overall gearing and actuator solutions."

Ted Karmazin, sales manager for Solo World Partners of Grosse Ile, MI, says his company has exhibited at the SAE World Congress for the last 10 years. Solo represents a number of medium- to large-volume manufacturers in the Far East, including Hota Industrial Mfg. and Shanghai Automotive. Solo will display a variety of steel gears, shafts, CNC machined parts and powdered metal parts for engines, differentials, transmissions and other powertrain components. The company emphasizes the low cost and high quality of the manufacturers it represents. Parts are manufactured at ISO-9000 and ISO-16949 registered facilities, Karmazin says.

The technical presentations at the SAE Congress will also include many gear-related topics.

For example, Saul Herscovici, president of Power Engineering & Manufacturing (PEM) Ltd. of Waterloo, IA, will be presenting "Increased Power Density, Efficiency and Durability with Megagears and Unimegagears."

Megagears and Unimegagears are trade names for gear designs developed by PEM Ltd. The company uses computer software to determine high pressure-angle designs that provide a larger area of contact, Herscovici says. "Through many years of research, we have increased the power density of gears 35–45%."

Complete information on attending the SAE 2005 World Congress & Exhibition is available using the contact information below:

SAE International
400 Commonwealth Dr.
Warrendale, PA 15096-0001
Phone: (877) SAE-CONG or (724) 772-4027
E-mail: *CustomerService@sae.org*
Internet: *www.sae.org/congress*

To Retain Quality: Gear Training from AGMA

You've got a new salesman, two new machine operators, and a 22-year-old engineer. They've been working for months, learning their jobs, but their training hasn't been as systematic as you'd like. You've also got a manager returning to the shop floor after five years in a front office. He should have a refresher in gear manufacturing.

They all need formal training. The operators and manager especially need training in troubleshooting. But you don't have the time.

AGMA does, though.

"Our class recognizes that most people directly involved in the gear manufacturing process have little or no formal education in the theory of gear geometry and its relationship with the process," says Geoff Ashcroft. "We feel that this knowledge is fundamental to retaining a quality manufacturing process."

Ashcroft, a gear manufacturing consultant, is an instructor for AGMA's Training School for Gear Manufacturing. He teaches the school's basic course through his company, Gear Consulting Group LLC, which is AGMA's contractor for this and similar programs.

The course, to be held June 13–15, provides classroom training in gears and their nomenclature, inspection principles, gear manufacturing processes—especially hobbing and shaping—and emphasizes troubleshooting.

"The emphasis is on the relationships between the three distinct aspects of gear production: making the teeth, inspection of the result and relating these two aspects through the underlying geometry," Ashcroft says. "This is essential for an understanding of why things go wrong and how to fix them."

Past students included machinists, technicians, engineers, quality managers, sales reps, managers and executives. The course is usually taught at Richard J. Daley College in Chicago and provides classroom and hands-on training. The June course will be held at Liebherr Gear Technology Co., located in Saline, MI.

EVENTS

The course costs $750 per person and covers classroom sessions, course manual and AGMA certificate of completion.

This course has been presented by Gear Consulting Group at other locations, including Gleason Corp.'s facility in Novi, MI. Gear Consulting Group also plans to provide the course Sept. 14–16 at Contour Hardening Inc., located in Indianapolis, IN.

For more information:
Gear Consulting Group LLC
P.O. Box 647
Richland, MI 49083
Phone: (269) 623-4993
Fax: (269) 623-2055
E-mail: *gearconsulting@aol.com*
Internet: *www.gearconsultinggroup.com*

More Than the Fundamentals: Gleason's Gear School

In a gear fundamentals course, students could expect to learn about spur and helical gears, the involute profile, and the mechanics of hobbing and shaping. But could they expect to learn what causes extreme ar than 12 teeth and a helix angle of more than 60 degrees?

They might not expect to, but they did at the course held Feb. 7–10 at Gleason Cutting Tools Corp.

The gears with lead variations were among several real-world manufacturing problems brought by attendees and discussed in class at Gleason Cutting Tools Corp., located in Loves Park, IL. Other problems involved tool wear, tool life, and catastrophic failures, with students asking how to troubleshoot the problems.

Called a gear fundamentals course, Gleason's program goes beyond basic explanations of the various types of parallel-axis gears and their gear manufacturing processes. Attendees at the February course learned what aspects of the gear cutting tool affect what aspects of the gear and which features of machine control affect which gear features. They learned, for example, about AGMA hob specifications and their relationships to gear specifications.

Given throughout the year, the four-day course is designed for people who are new to gear manufacturing and covers gear types and ratios, gear tooth systems, general formulas, gear manufacturing methods, and inspection, both functional and analytical. It also covers high speed steels and the differences between tool tolerance and gear tolerance. The course is taught by Gleason employees involved in engineering, production and inspection. Moreover, students can tour the facility so they can see the practical applicability of their lessons.

The course costs $895 per person. The cost covers handbook, all class materials, all lunches and one group dinner. It doesn't include hotel room, though hotel arrangements are made for attendees by Gleason Cutting Tools. For the February course, students stayed at Cliffbreakers Hotel and took hotel shuttles between it and Gleason Cutting Tools' nearby facility.

The class is kept small, no more than 15 people, so instructors can address students' individual concerns. In February, the class consisted of 11 attendees. They included machine operators, engineers, managers and a quality control supervisor.

The course will be held again April 11–14. Gleason Cutting Tools can also provide the course at gear factories and other facilities. The company also offers a second course on advanced gear process dynamics.

As for the gears with lead variations, John Lange recommended looking at three factors: face-to-bore clamping surface perpendicularity in the gear blank, wobble in the hobber's fixture, and the fixturing in the inspection machine. An instructor, Lange is product manager, regional products–Americas for Gleason Cutting Tools and has been in the gear industry since 1970.

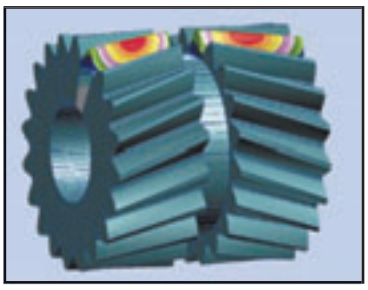
Lange didn't know whether one, two or all three factors were responsible, but he was sure that looking at them would solve the lead problem.

"One hundred percent," he said. "Those are the things that cause it."

For more information,
contact the Gear School Coordinator:
Gleason Cutting Tools Corp.
1351 Windsor Road
Loves Park, IL 61111
Phone: (815) 877-8900
Fax: (815) 282-0281
E-mail: *gctc@gleason.com*
Internet: *www.gleason.com*

EVENTS

Papers Being Chosen for International Gear Conference



More than 100 abstracts have been selected to be developed into technical papers for the 3rd International Conference on Gears, scheduled for Sept. 14–16 in Munich, Germany.

"The presentations are expected to emphasize future trends in the design, development and applications of gears and transmissions," said Heyjo Jacobi, product manager–conferences for VDI Wissensforum (the VDI Center for Advanced Training). Jacobi, who holds a doctorate in mechanical engineering, is responsible for the conference.

The abstracts were selected among 220 submitted by authors from 25 countries in Europe, North America and Asia.

"The highest amount of abstracts we have ever gotten," Jacobi said. "The high amount of potential presentations gives us again the opportunity to increase the scientific and technical level of the conference."

The center chose the best 110 abstracts, asking selected authors to develop their summaries into technical papers for presentation. The abstracts covered gear design, production, testing, industrial applications, and research and development.

The conference allows gear researchers to present the most recent results of their work, teaching attendees about the state of the art. "The conference will offer participants the opportunity to discuss these results in detail and share their experience," Jacobi said.

The conference will be held in Munich, the capital of Bavaria. Jacobi described Bavaria as a center of the automotive industry in southern Germany.

Jacobi said he expects more than 300 people to take part in the conference, about 50 more than participated in the last conference, held in 2002. The conference's program and registration form will be available by April 15.

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Dan Bailey, Fred Sowinski, Marilyn Bergmann, Stan and Zdenska Sitta at AGMA's Old Goats' Dinner.

AGMA Toasts Past Presidents

The Pfister Hotel in Milwaukee, WI, hosted the "Old Goats' Dinner" honoring past American Gear Manufacturers Association presidents on October 2–3.

The dinner was held alongside the association's fall technical meeting. Current AGMA chairman Fred Sowinski presented a posthumous award of excellence to former AGMA president Bob Bergmann. His widow, Marilyn, was present to accept the award on behalf of her late husband's 35-year contribution to the gear industry.

Other former AGMA presidents in attendance were Stan Sitta and Dan Bailey.

April 4–7—WESTEC '05 Annual Exposition and Conference. Los Angeles Convention Center, Los Angeles, CA. The West Coast's largest manufacturing and metalworking exhibit. Seminar topics include lean manufacturing, prototype deburring, and global manufacturing. Registration is free. For more information, contact the Society of Manufacturing Engineers on the Internet at *www.sme.org*.

April 26–27—Plastic Gear Technology Seminar. Universal Technical Systems facility, Rockford, IL. An introductory course in plastic gearing. Attendees will discuss case studies involving The Ohio State University's Gear Lab, the engineering plastics material operations at Ticona, tooling and parts manufacturing at UFE, and plastic and metal gear design at Universal Technical Systems. $1,250. For more information, contact Universal Technical Systems by telephone at (800) 435-7887 or on the Internet at *www.uts.com*.

May 24–26—EASTEC Advanced Productvity Expo. Eastern States Expo Center, West Springfield, MA. An annual manufacturing event that will introduce the Smart Machining & Job Shop Center as well as the Lean Manufacturing and Quality Resource Center. Sponsored by the Society of Manufacturing Engineers. Registration is free. For more information, contact SME by telephone at (800) 733-3976 or on the Internet at *www.sme.org*.

ASME Presents Patent Award to Litvin

Faydor L. Litvin

Faydor L. Litvin, professor of mechanical engineering and director of the Gear Research Center at the University of Illinois at Chicago, was 2004's recipient of the American Society of Manufacturing Engineers' Thomas A. Edison Patent Award.

Litvin's patent, called the "Apparatus and Method for Precision Grinding Face Gears," has provided a means of reducing the weight of helicopter transmissions by 40%, thereby promoting fuel savings and reduced emissions.

Litvin invented a process that grinds hardened face gears that can be manufactured with the same safety features as spiral bevel gears.

Mel Torres, media manager at ASME, says the Thomas Edison award is the most prestigious granted by the association in Litvin's field.

"In the area of patents, this is the highest ASME accomplishment," he says. "Faydor Litvin was nominated by his peers because of the creativity in developing a process that enhances the field of mechanical engineering."

The Boeing Co. is currently working with Litvin's patent. Face gears for an upgrade of the drive system for the Apache attack helicopter utilized by the U.S. Army were created with Litvin's principles in mind.

Terrell Hansen, Boeing's department manager for drive system design, says they make gears with the ideas outlined in Litvin's patent on a daily basis.

"Because of Professor Litvin's innovation in grinding face gears, we now have a higher reduction ratio in a gear set. This means we can get rid of hardware and some of the weight, which results in lower costs for designers, builders and operators of the system," he says.

This is the third patent that Litvin holds, and his research is credited with 25 inventions. Mostly, his research focuses on mechanisms, manipulators, theory of gearing, computerized design and the simulation of meshing of gear drives.

Litvin has been at the University of Illinois at Chicago since 1979, when he arrived in the United States.

Much of his time was divided between teaching and writing, and he is credited with 300 publications, including 10 monographs.

The ASME was established in 1880 for the engineering and technology community. The association's honors and awards program is funded by the ASME Foundation.

Wind Farms that Don't Need Government Subsidies?

In America, manufacturers of utility-scale wind turbines—and manufacturers of their gears—know the U.S. wind energy industry depends a lot on the federal government's wind energy tax credit. Wind energy developers may even suspend their projects if they don't have the credit.

In Norway, though, ScanWind Group AS is erecting 14 three-megawatt wind turbines to answer a question: If the company produced these turbines, could wind farms using them compete with other energy sources, without government subsidies?

The answer, whatever it is, will come from the company's Hundhammerfjellet wind farm, located along Norway's west coast, where the turbines are exposed to the winds of the Norwegian Sea, north of the Atlantic Ocean.

The key to a "Yes" answer is ScanWind's ability to build wind turbines that last 20 years. According to Torolf Pettersen, the company's managing director, turbines around the world operate at full load for an average of 2,300 hours each year. In Norway, the average is 3,900 hours. Given the country's situation, ScanWind figured if it could build turbines that lasted 20 years—and Pettersen maintains it can—then: "We can build wind power in Norway cheaper than any other type of new electricity—including gas power," he says.

ScanWind is creating the Hundhammerfjellet wind farm with both geared and gearless wind turbines. The project consists of three phases: 1.) installing a 3000 DL demonstration turbine, completed during winter 2003, 2.) installing a 3000 GL demonstration turbine, completed during fall 2004, and 3.) installing 12 more three-megawatt turbines, creating a wind farm with a 42 megawatt capacity.

ScanWind's 3000 DL is a three-megawatt turbine made for onshore use and equipped with a direct-drive generator. The 3000 GL is also a three-megawatt turbine for onshore use, but it's built with a special gear assembly that lets the turbine use an asynchronous generator.

Pettersen says the project's original two turbines have been performing very well and producing little noise. ScanWind expected to start producing the remaining 12 turbines this spring and start installing them in spring 2006, with all 14 turbines operational in fall 2006.

Star SU Hires New Personnel

Star SU recently hired four new employees for its sales and technical efforts. Kit Pridmore has joined the company as a technical service manager. He has worked at Gleason in the same position for the past eight years and at American Pfauter for nine years prior to that. Pridmore will be based out of Detroit and will be responsible for technical support to customers in Detroit and parts of northern Ohio.

Kit Pridmore

Rick Ruffin

Rick Ruffin was hired as a regional sales manager for the southeastern United States. He will operate out of Charlotte, NC. According to the company's press release, Ruffin has held similar positions at Gleason Cutting Tools and Perrin Precision Tools.

Mark W. Raby will manage the cutting tool sales operations in southeastern and south central Michigan. He has worked in powertrain manufacturing technical service sales for nine years at Mapal in Port Huron, MI. In addition, he has extensive experience in prototype R&D and as a journeyman apprentice.

Mark W. Raby

Rick Mattingly

Rick Mattingly joined Star SU as manager of tool services. He held similar positions at Pfauter Maag Cutting Tools, Barber Colman and Gleason since 1969. Mattingly will be based in the company's Hoffman Estates, IL, facility.

St. Denis Promoted at HD Systems

Brian St. Denis

Brian St. Denis was promoted to vice president of HD Systems from his previous position as engineering manager.

According to the company's press release, he has been with HD Systems for 12 years.

HD Systems of Hauppauge, NY, is a manufacturer of harmonic drive gearing and motion control products.

Ikona Gear Signs Agreement

Ikona Gear has entered into a development agreement with StarRotor Corp. to provide patented Ikona Gear technology for the third generation of StarRotor's proprietary design engine.

According to Ikona's press release, both companies will develop and test the patented Ikona Gear tooth form and later negotiate a licensing agreement with royalties based on StarRotor's net engine sales. Both companies will file separate patents to protect their intellectual properties.

Ikona has also entered into an unrelated non-disclosure agreement with Paccar-Winch Division of Paccar Inc., in which both companies will collaborate to assess the adequacy of Ikona's slew ring and D-drive differential technologies in Paccar's new winches and hoist drives.

If the results prove successful, Paccar will gain exclusive distribution rights within the winch industry.

Höfler GmbH Celebrates Significant Anniversaries With Hofmann

On February 1, Hagen Hofmann observed his 40th anniversary with Höfler GmbH and his 65th birthday.

According to the company's press release, Hofmann started as a design engineer in 1965 and convinced the company's founder, Dr. Ing. Höfler, to develop gear manufacturing equipment of all sizes and types. That same year, the first Höfler gear grinder was introduced. Hagen Hofmann was appointed president of Höfler Maschinenbau GmbH in 1990.

New Board Member at American Axle

American Axle & Manufacturing Holdings Inc. appointed Larry K. Switzer to its board of directors.

According to the company's press release, Switzer has held numerous positions in finance. Before his retirement in 2000, he was CEO of Danka PLC and led the company into a successful restructuring and turnaround.

American Axle & Manufacturing designs, engineers, manufactures and validates driveline systems and related components for various automotive applications.

Estudio Piña Certified to ISO 9001: 2000

Estudio Piña received its ISO 9001: 2000 certification for the scope of technical assistance services in mechanical gear drives and applications.

According to the company's press release, the certification covers any service offered to customers in Argentina and Latin America.

Marposs President Receives Japanese Marketing Award

Stefano Possati, president of Marposs S.p.A., received the News Digest Marketing Award for 2004.

The award was presented to Possati at News Digest Publishing's annual meeting in Nagoya, Japan. It was the second time in the award's 22-year history that a non-Japanese company has been so highly recognized.

Stefano Possati (left) receives News Digest Marketing Award for 2004.

Fifty Japanese operators representing the manufacturing community selected Possati on the basis of four criteria. According to the company's press release, Marposs possesses the largest share of in-process measuring equipment, applies quality metrology technology to a variety of products, offers worldwide support for specific market integrations and solves in- and post-process measurement applications in workshops.

RoMaDyn Opens Rotating Machinery Consultancy

RoMaDyn of Minden, NV, will offer global consultancy on rotating machinery dynamics.

According to a press release, the new company will offer machinery diagnostics, product services, and technical seminars on rotating machinery assets and other topics. Machinery diagnostic services include finding the root cause of malfunctions in turbines, compressors, motors, generators and pumps. Product services include installation, verification, repair and maintenance of vibration instrumentation. Seminars will cover balancing, alignment, vibration monitoring system operations and maintenance and externally pressurized bearings. G. Richard Thomas will lead the operation as global services manager. Thomas authored a comprehensive textbook titled *Fundamentals of Rotating Machinery Diagnostics* and has extensive industry experience.

In Memoriam
Gear Manufacturer Bennie L. Boxx: 1935–2005

Bennie L. Boxx, founder of B&R Machine and Gear Corp. of Sharon, TN, died Jan. 2 of blood cancer. He was 69 years old.

Mr. Boxx worked in the gear industry for more than 50 years, starting as a 15-year-old employee of Industrial Gear of Chicago.

Mr. Boxx was born March 28, 1935, in the small farming community of Sidonia, TN. Eight years later, his family moved to Chicago. Mr. Boxx attended high school in Chicago but dropped out to earn money. His first job in the gear business was at Industrial Gear.

He later left In-dustrial Gear to work at Arrow Gear Co. of Downers Grove, IL, where he learned about spiral bevel gears. Over the years, Mr. Boxx worked for a number of other gear-related companies, including Balfre Gear, Brad Foote Gear Works, and Cadillac Ma-chinery.

Bennie L. Boxx, Founder of B&R Machine and Gear Corp.

"He was an honest and honorable individual," says Michael Goldstein, president of Cadillac Machinery, "and he was extremely talented in his bevel gear ability." Mr. Boxx, however, was with the company only briefly, Goldstein explains. "He enjoyed making gears much more than selling gear machines."

In the early '70s, Mr. Boxx and two friends started their own gear company, Astron Gear in Hodgkins, IL. Within a few years, he sold his share of the company and started B&R Bevel Gears and Machine, located in Addison, IL. The company had three employees during its first year; B&R has 30 today.

By late 1980, B&R Bevel Gears moved from Illinois to Tennessee. In '77, Mr. Boxx was visiting his hometown of Sidonia when he noticed an empty building once used by Central Southern Trucking in Sharon, a nearby town. He decided to open a branch of B&R Bevel Gears in the building. In '78, his eldest son, Bennie R. Jr., moved to Sharon and opened B&R Machine and Gear Corp. Within three years, Mr. Boxx merged the two operations.

The merged company started in a 7,000-square-foot building. Owned and operated by the Boxx family, B&R now consists of five buildings, more than 135,000 square feet, on 22 acres.

Mr. Boxx is survived by his wife, Doretta; two sons, Bennie R. and Terry; two daughters, Brenda Sudzum and Suzette Kelly; a brother, Danny; two sisters, Joan Rollins and Carolyn Burnett; 13 grandchildren and three great-grandchildren. He was preceded in death by a daughter, Doretta Denise Boxx.

B&R continues.

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Gear Tattoos

Imagine a shop supervisor with a three-gear drivetrain tattooed on his bicep or a saleswoman with a tiny spur gear silhouetted just above her ankle.

Now imagine hundreds of gear people supporting their industry by getting **Gear Tattoos**. That's a grassroots campaign the Addendum team could get excited about, and it would help us forget about our last campaign.

As readers will recall, we suggested in the September/October issue that the gear industry start a grassroots campaign to put the face of Edwin R. Fellows, inventor of the gear shaping machine, on the $10 bill. We kicked off the campaign by calling the United States Treasury with our idea. We even invited our gear comrades to join by calling us so we could give them the Treasury's phone number.

Strangely, no one called.

We assumed our gear fellows took the initiative and called the Treasury themselves, so we phoned to see how many people joined our campaign. The department's receptionist seemed a little confused about our request, but she said she'd ask around the office. We waited a month, then two, for a call back. We didn't get one.

Eventually, we decided if we wanted responsiveness, we shouldn't go to the federal government. We should go to the gear industry itself. After all, we're all about short lead times and getting things done.

So the Addendum team started thinking: How else could gear people publicly show their support for their industry?

Then it hit us: **Gear Tattoos**.

With this campaign, we don't need to rely on the Treasury to change the $10 bill. We can change our bodies ourselves. Now the tattoo can be simple, the spur gear silhouette, or complicated, a mechanism's gear assembly.

The Addendum team went the complicated route—well, one of us did. He was in a Jim Beam slumber that Friday night. That was just as well. It took the artist several hours to do the whole tattoo. After waking, our teammate was surprised by our decision. He later saw the usefulness of a gear tattoo, though. If we want to start a grassroots campaign, we have to be willing to take the first step.

Now our teammate's tattoo (pictured above) is on his left forearm. To show it off, all he has to do is hold out his arm or, at most, roll up his sleeve. That's important. The gear tattoo has to be on a body part that can be shown in public, in mixed company. This campaign is about *publicly* showing our support for our industry: No tattoos where zippers have to be undone or clasps unhooked.

Now it's March. Gear Expo 2005 is in October. That gives us seven months. By the time we get to Detroit, we should all have our **Gear Tattoos**. The Addendum team has already called Cobo Center's receptionist and asked to reserve a room so exhibitors and attendees could show off their tattoos. She wasn't sure a room would be available, but said she'd ask around the office.

We'll give her a month to call back.

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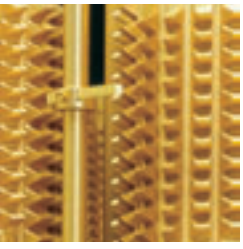







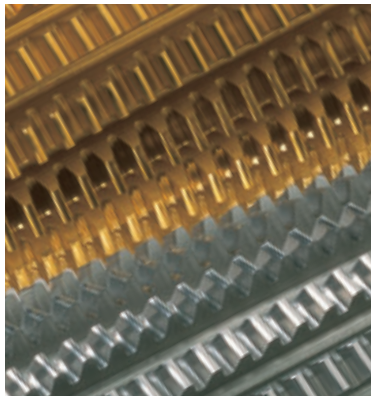



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