GEAR GRINDING 1995

Technology and trends show that grinding's future is not so rough.

William R. Stott

Gear grinding is one of the most expensive and least understood aspects of gear manufacturing. But with pressures for reduced noise, higher quality and greater efficiency, gear grinding appears to be on the rise.

OSHA regulations and customer demands are forcing gear manufacturers to examine ways to make noisy printing presses and rolling mills purr like kittens rather than roar like lions. And drivers want their sedans to roll along on puffy white clouds rather than on rough and noisy thunderheads.

"I never thought I'd see the day when we'd have rolling mills with ground gears, but here we are with rolling mills ground to helicopter tolerances," says Brian Cluff, vice president–technical sales for American Pfauter.

For a big, expensive operation like a rolling mill, having a gear failure can cost hundreds of thousands of dollars per day. Ground gears will run smoother for longer. If that saves a company money in the long run, it makes a lot of sense, Cluff says.

Other manufacturers who are looking more and more to grinding include makers of automobiles, trucks and motorcycles. Harley-Davidson, for example, began grinding gears on some of its 1995 models and is expected to expand grinding operations for 1996. With the average motorcycle buyer looking more like a middle-aged yuppie than a long-haired, tattooed, black-leather biker, the appeal of the loud bike is getting smaller.

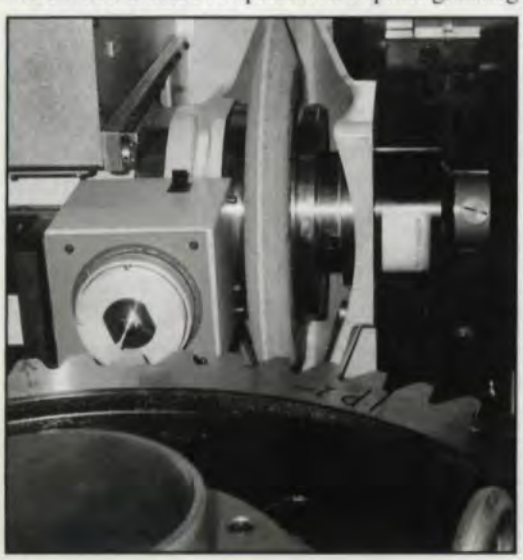

Photo courtesy of Höfler GmbH.

On-machine measurement will continue to play a big role in grinding technology.

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The demand for ground gears seems to be spreading faster in Europe than in the United States. For example, the spiral bevel gears in European truck axles are now being ground in large numbers, says Mark Smith, gear product manager for Ernst Winter & Son, manufacturers of gear grinding wheels.

In the United States, grinding of bevel and hypoid gears is almost unheard of outside the aircraft industry. But it's an area that's going to attract a lot of attention in the next few years, says Robert G. Hotchkiss, director of applications engineering for the Gleason Works. In car and truck manufacturing, grinding will become an environmentally friendly alternative to lapping, Hotchkiss says. In addition to reducing gear noise, manufacturers won't have to dispose of the gritty, messy lapping oils.

In addition to noise and environmental concerns, the demand for ground gears will be based on increased load-carrying capacity, says Matthew Babisz, president of Niagara Gear, a job shop specializing in ground gears. "When I bought this company 20 years ago, I concentrated on grinding. I could see the trend. People were looking for greater horsepower, higher speed and accuracy, and less noise."

With greater demand, manufacturers are looking for ways to increase the productivity of their grinding machines. One of the main improvements to machines over the past few years has been the development of more sophisticated computer controls.

The interfaces used on today's CNC machines are beginning to look more and more like the screens on our PCs at home and in the office. For example, the Oerlikon Opal 500 is run by a 486-66mHz PC with a Windows-NT control. The Pfauter-Kapp gear grinding machines also use a Windows environment. Programs for the

Reishauer RZ 820 machine can be prepared on a detached PC and downloaded to the machine. The Höfler machines can be equipped with a modem, which allows engineers in Germany to troubleshoot a machine without sending a service technician. When problems can't be solved over the phone, the technician will have a good idea of what needs fixing before he comes to the site.

By making the machines easier to use and capable of storing more setups and programs, the machine tool manufacturers have gone a long way toward making gear grinding machines more productive. "In the old days, you could spend a whole day or days setting up index plates and sine bars. Today, with a CNC machine, it takes 10 to 15 minutes for a preprogrammed part," says Don Kosal, sales engineer for National Broach.

In addition CNC controls improve the grinding process. "Burning of the gear is the greatest factor that inhibits reducing the costs of gear grinding," says Carl Eckberg, vice president for gear products, Bourn & Koch. "Our customers want to be able to produce more parts in less time for less money. They want to know how we can build machines to reduce the burning of the part and/or grinding cracks when feeds and speeds are increased." Advanced CNC controls allow machines to grind faster and deeper by varying the grinding cycle. "CNC can allow the machine to alternate grinding areas so that one area won't get too hot while another area is sitting cold," Eckberg says.

Also, CNC allows grinders to produce modifications to lead and profile that previously were either impossible or too time-consuming to be economically practical. "The introduction of CNC control technology has not only improved the efficiency, reliability and accuracy of gear grinding machines, but it has also opened the door to a wide variety of gear grinding process improvements," says Stephen Price, vice president of Höfler. Such improvements include workpiece management programs, automatic start and finish grinding, special relief modifications and on-machine gear inspection, Price says.

One area to watch in the coming years is on-machine measuring systems that automatically adjust the way the machine operates. Many machines already have some form of on-machine monitoring or sensing device to stop the machine or notify the user when the part being ground is no longer within specified tolerances. For example, on the Pfauter-Kapp machines, the user can input the profile tolerances and have the machine automatically dress the wheel or alert the user when the wheel needs to be changed. The advantage is especially noticeable for large parts, such as those the Pfauter-Kapp machines are used to grind. Rather than unloading a large, heavy gear and reloading it on a CMM, you can tell while the gear is being ground whether it is up to specifications.

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The Reishauer RZ 820 machine features a quality control module, which monitors the transient load oscillations that occur as the gear's teeth come in and out of contact with the grinding wheel. The machine evaluates and then counteracts any errors.

"Touch grinding" is one of the features touted by the manufacturers of the Niles gear grinder. An acoustic sensor detects typical or atypical grinding noise and can start or stop a specific action of the machine, depending upon what it detects. This is useful for aligning the workpiece to the grinding wheel and for automatic stock dividing. Niles grinders also have an optional remote diagnostic system with gear measurement on the machine.

Höfler's on-machine inspection equipment displays the results of lead, profile, spacing and modification inspections on a portable color screen. Results can also be printed out for quality control documentation, and data can be used for automatic machine corrections.

With machine speeds and feeds continually increasing, the pressure and placement of the lubricant nozzles have also come under close scrutiny. Theoretically, the more efficiently the hot chips are removed, the faster the machine can grind. Modern machines use high-pressure lubricant delivery systems with multiple nozzles. Some also have air jets to further direct the lubricant flow.

Coolant configurations will have to become more and more flexible as coolants and their setups become more and more customized to a particular application, says Dave Matheson of Liebherr.

Grinding is getting more user-friendly, with PC-like screens and easy-to-use controls, as shown by the Höfler interface at right.

Photo courtesy of Höfler GmbH.

In addition, "Gear manufacturers are just now beginning to understand the effect the right grinding fluid can have," says Carl Eckberg of Bourn & Koch. Advances in coolant materials will allow gear manufacturers to become more environmentally friendly. Despite the fact that synthetic and water-soluble lubricants are now available and being developed every day, 90% of all gear grinding is done with straight oil, says Kris Kumar, applications engineer with GE Superabrasives. Alternative materials will probably be used more and more, he says.

One of the areas where coolants are going to play a more important role is in grinding parts from solid, Matheson says. Many of the machine tool manufacturers have been experimenting with and touting their machines' abilities to grind through-hardened parts from solid, eliminating the hobbing or shaping process altogether.

Traditionally, it has been economically practical to grind from solid only the smallest, finest-pitch gears. Today that's changing. The Sigma Pool companies have been doing extensive tests on grinding from solid. An example is a 6DP, 29-tooth, 1 1/2-inch gear ground from solid in 14 minutes. "Six months ago we didn't know we could grind from solid," Matheson says, "In the next five years, we'll probably be able to grind anything from solid."

American Pfauter's Brian Cluff agrees. CBN technology has allowed grinding from solid to eliminate processes and save money. Despite common notions, it can be done with aerospace alloy steels, and it can be done on gears larger than 20", Cluff says. "We can grind gears 1DP and coarser from solid. In some cases, there's no other way to make the gear except to grind it from solid." Internal gears are a natural, Cluff says. *That way, you don't have to have a dedicated* shaping machine with specialized internal tooling.

Other companies have also been experimenting with various methods for rapid stock removal. Höfler promotes its machines' ability to combine deep feed grinding with double flank grinding, which, according to the manufacturer, accomplishes in one grinding pass what would take three or four passes using conventional generating grinding.

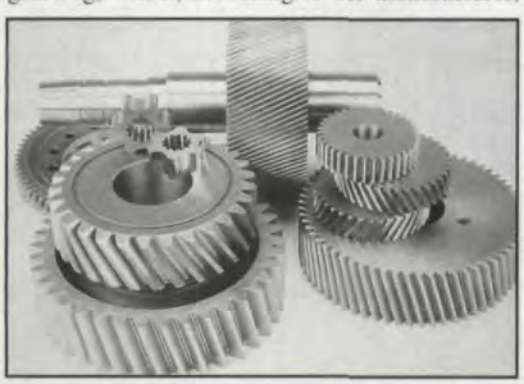

Photo courtesy of Reason Works.

With concern over gear noise increasing, more and more gears are being ground.

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Edgetek Machinery Co. is interested in applying a technology called high efficiency deep grinding to gearing. Edgetek produces a CNC grinding machine with a 35hp spindle that is capable of up to 40,000 sfpm using electroplated CBN wheels.

Wes Lee, president of Edgetek, says high efficiency deep grinding could provide 4–5 times the efficiency of creep-feed grinding with up to a 40% reduction in cycle times. Edgetek's technology is currently being used to produced splines, slots and other gear-like forms.

Although CBN technology has been around for about 15 years, it remains one of the least agreed-upon topics in gear manufacturing. Part of the problem is that every machine tool manufacturer has tried to carve out its own niche in the market. Certain grinding machines are geared toward using electroplated CBN wheels, while others try to take advantage of vitrified aluminum oxide wheels. Because competition is so fierce, it's no surprise that the manufacturers are reluctant to talk about their competitors' technologies.

There is no question that CBN is an outstanding material. Its metal cutting qualities have been well documented. It's hard—nearly as hard as diamond. Its structure is such that is stays sharper for longer than other materials. It sounds like a wonder-material. And for many applications, it is.

But there is a great deal of misconception about the best uses for CBN grinding. According to Brian Cluff of American Pfauter, the misconception is that CBN is cost-effective only for high-volume production. "Plated CBN grinding is cost-effective both for large and small lots," Cluff says. *"It's cost-effective for one gear."* Cluff points to a major gear job shop that produces very large, very expensive gears with CBN grinding.

On the other hand, Gary Rackley, president of Pro-Gear Co., which specializes in gear tooth grinding, says the misconception is that electroplated CBN wheels are the way to go for every application. Pro-Gear uses seeded gel wheels. And Matthew Babisz, president of Niagara gear, which also specializes in ground gears, says, "Electroplated CBN is good stuff, but it's very expensive. We use ceramic-type wheels."

Each manufacturer of gears has his own product mix and will have to choose his own optimum grinding technology. It is difficult to generalize about what is the state of the art in gear grinding when it is different for each application. You can buy an awful lot of vitrified-bond aluminum oxide

wheels at $35 each before you can justify the $2,000 or more it might cost for an electroplated CBN wheel. But on the other hand, it may be important to finish a large, expensive part as quickly as possible, so the cost may be justified.

To make matters more confusing, a great deal of work has been done in recent years to improve the bonds used with aluminum oxide and other conventional materials. "The area that we're getting some of the biggest surprises in is in vitrified wheel technology," says Dave Matheson of Liebherr. "We've been able to increase aluminum oxide grinding cycle times to nearly as good as CBN cycle times by putting more air space in the grinding wheel. We've been able to put so much air space in the wheel that you could hold one up to your mouth and blow out a candle through it." The air space allows for less material buildup, which in turn allows for greater stock removal.

"There is a definite trend back to the basics," says Stephen Price of Höfler, "That is, back to dressable aluminum oxide and corundum."

Because of the advances in vitrified-bond technology, the movement in the industry also seems toward dressable CBN. The advantages of this technology are a more stable finish, a more consistent level of material removal and a more consistent level of heat generated, because the wheel is constantly being adjusted to present an accurate profile, says John Ferriola, product manager for Ernst Winter & Son. In addition, with dressable wheels, when a minor print change comes down, you don't have to order a new wheel. You can reprofile the one you have.

Most of the grinding machine manufacturers will tell you that their machines are capable of using dressable CBN technology. But capable doesn't necessarily mean practical. In fact, the use of dressable CBN is not very widespread. Vitrified-bond CBN is dressable, but only to a certain extent, says Ronald Halama, sales manager for WMW Machinery Co., which represents the Niles grinder in America. Because CBN is so hard, it must be dressed with diamond tools. Making major adjustments to a dressable CBN wheel causes great wear and tear on the dressing tool, and also results in throwing away large amounts of expensive CBN material, Halama says.

The Sigma Pool has researched the use of vitrified-bond CBN wheels. "We got more parts than with standard vitreous wheels, but it took longer to dress and it ate up the dressing wheel. The technology is not there yet," says Dave Matheson of Liebherr.

However, there are companies using dressable CBN grinding with great success, says Brian Cluff. Dressable CBN is applicable for a variety of industries, he says.

"Grinding has got to be economically viable from the viewpoint of cost per piece. It's hard to nail down the value of improved quality or reduced noise, so it's not easy to justify in every case." —Robert G. Hotchkiss, Gleason Works

Because there are so many different technologies involved in gear grinding, it's important for manufacturers to have a solid understanding of them all. Most of the machines on the market today are capable of using either electroplated or dressable wheels. In many cases, it's up to the gear manufacturer to decide what process is going to be most cost-effective for a given application.

The cost of gear grinding is one of the key factors that has prevented its widespread use, and it's not always easy to justify. "Grinding has got to be economically viable from the viewpoint of cost per piece," says Robert G. Hotchkiss of the Gleason Works. "It's hard to nail down the value of improved quality or reduced noise, so it's not easy to justify in every case."

In fact, a number of alternative technologies have been experimented with as replacements for hard finishing gears by grinding, but grinding's place seems secure. "I've been in the gear business for 40 years and in the grinding part of the business for 30 years," says Niagara Gear's Matthew Babisz. "I've seen them try just about everything—from carbide hobbing or skive hobbing to ausrolling to trying to control the heat treating process—and it just doesn't work. Grinding is still the best solution." ⚙

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