

THE "HOLE" STORY ON GEAR QUALITY



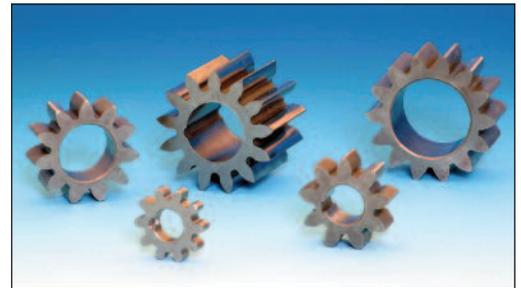
A two-position rotary table with automated part loading by servo robot allows high-volume processing in unattended mode, while holding tolerances as tight as 0.000050 (1.25 μm). Protective doors removed from front of machine for photos.

Roscoe, IL. – Forest City Gear President Fred Young has a straightforward philosophy for acquiring and retaining business. The company's strategic directive is: "Excellence without Exception." It boils down to always giving the customer a higher level of quality than specified on a print – or in any other interaction with a customer. "The goal is to do this without adding much cost or time to a job," Young explains. "We do everything we can to distinguish our product from competitors', and we try to do it inexpensively. On bore-type gears, we have found that automated honing is a good way to give the customer tighter control of bore size, roundness, straightness and finish. The customer notices the difference in a smoother, quieter, more efficient drive, and unless we stumble in some other aspect of the job, we will have a repeat customer. The trick in gear manufacturing is to add this value without adding cost for the customer."

Forest City Gear's principle products are fine and medium pitch custom gears, such as internal, spline, sprocket, helical, spur

and worms/worm gears. The company works to quality levels as high as AGMA 15 (DiN 2-3). Part runs range from one to several hundred thousand. Maximum O.D. on most parts is 20 inches (508 mm), except for worms (5 inches/127 mm) and worm gears (16 inches/406 mm). Typical materials include 12L14, 1215, 4140, 8620, 9310 and various stainless grades, as well as aluminum, bronze, brass, Inconel, Hastelloy, titanium, plastics, wood fiber and powdered metal.

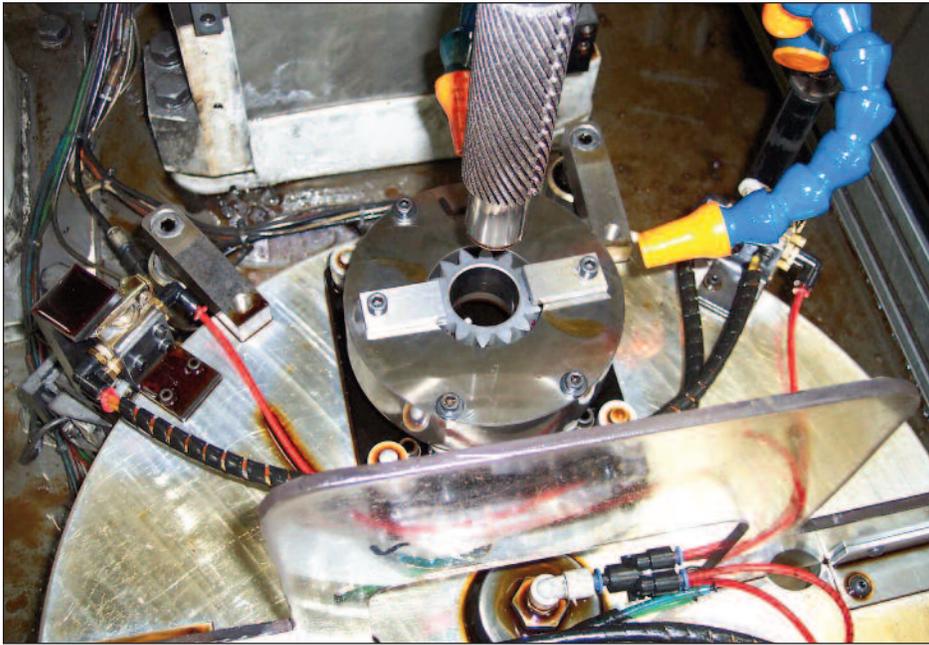
About 30% of the company's work is aerospace-related, 5-10% medical, 5% military, and the remainder is industrial or instrument work. Customers include Boeing, Airbus, Cessna, and Beechcraft as well as the space shuttle, the space station, Martian rover vehicles and the Abrams tank. Forest City produces gears for several motorcycles and race cars, as well as one of the few bait



Spur pump gears are typical parts honed by Forest City Gear. Keyways, blind (as in left foreground) or standard, are common features where honing helps remove burrs while producing final hole size and finish.

casting reels made in the U.S. Many of these applications demand high process capability where honing provides critical advantages in control and consistency, according to Young. The company also invests aggressively in training and the latest technologies to make the shop one of the most modern in the world.

**(continued)**



Large-bore gear about to be honed with Sunnen CGT Krossgrinding® tool. The tool allows control of bore size to 0.00005" (1.25µm) and can achieve 16 microinch finish or better. Tool life on soft steel gears is about 250,000 parts.

### The choice to hone

Forest City Gear has used honing since the inception of its business. Young says the company also tried hard turning, but found it more difficult to control quality, especially for microfinishes. "ID grinding is a fine process for gears with larger (>0.75 inch/19 mm) bores and low L/D ratios (0.5:1), but our range of work includes smaller diameters and relatively deep bores," he explains. "When you start to reach an L/D of 2:1, honing has a real advantage in speed of material removal, and over 5:1 you might start to see deflection on a grinding spindle, exacerbating taper issues. We still outsource parts for ID grinding, such as those with a blind hole where a counterbore leaves no relief for a honing tool."

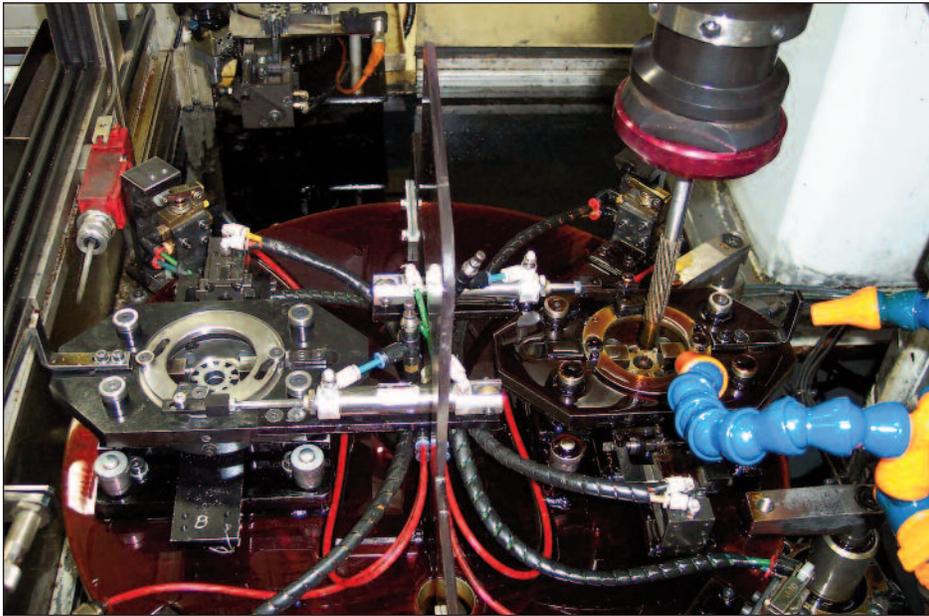
Precision ID grinding machines are several times more expensive than an equally capable hone, he adds. Even more important is that accuracy for the grinder is dependent on the machine's positioning capability, while accuracy is mostly tooling dependent with a hone. Periodic checks, calibration and refurbishing are needed to

ensure positioning tolerances on a grinder. Honing tools are simple and rigid. When they wear, they are replaced. Unlike a grinding wheel on the end of an arbor, the honing tool isn't subject to bending forces. The tradeoff is that any given honing tool is suitable for a very limited range of diameters, so more honing tools need to be stocked than grinding wheels.

Two other points are worth noting about ID grinding and hard turning, Young explains. "If a part comes off a hone just a little too small, you can re-run it, while that's much more difficult, if not impossible, with ID grinding. Also, turning and grinding can't produce honing's characteristic crosshatch pattern on the bore surface. This has proven a desirable feature for maintaining an oil film for rotating gears."

### High $C_{pk}$ holemaking

When working to high  $C_{pk}$  requirements, Forest City Gear finds the high resolution of the tool feed system and consistent nature of honing give it a real advantage in targeting and holding a dimensional sweet spot. This is critical because high  $C_{pk}$  requirements means the band of variability around target values has to be reduced, Young states. "For rule-of-thumb purposes, when the target is 1.33  $C_{pk}$ , we shoot for about 60% of the print tolerance; at 1.67  $C_{pk}$ , the target is 40% of tolerance," he says. "A tolerance of five tenths on bore size, thus, shrinks to three tenths or less when six sigma quality requirements are imposed. Various holemaking processes, such as boring, drilling and reaming are capable of holding good tolerances, but when a high  $C_{pk}$  requirement is imposed, honing has the advantage in control and consistency. With automated honing, we can easily control tolerances to 50 millionths of an inch  
*(continued)*



Autoloading fixture can run over 30 different parts and allows correction of perpendicularity, if needed. Small-bore gears in photo are being honed with Sunnen's CGT Krossgrinding® tool.

(1.25  $\mu\text{m}$ ). In fact, we have run capability studies where we've hit double-digit  $C_{pk}$  levels when honing for bore size."

### Honing a bore-type gear

One of Forest City's core products, pump gears, start as flat, washer-type blanks made on a screw machine. These gears operate in a small, precision housing, so any perpendicularity error in a shaft-mounted gear causes wobble, loss of efficiency, noise, increased friction and possible leakage. An adage of gear making is that a gear can be no more accurate than the blank from which it starts. On a bore-type gear, this means starting with parallel faces and a perpendicular, round bore with parallel walls, and no taper or bellling. Forest City's minimum standard is 0.0005 inch (0.0127 mm) for parallelism and perpendicularity, and the shop can work to tighter tolerances as gear quality dictates.

The pump gear blanks are double-disc ground for face parallelism and width, then rebored on an automated lathe to re-qualify the perpendicularity. Some stock is intentionally left in the bore so that final ID size and finish can be set on a hone. Pump gear blanks are usually stack hobbled.

They are grouped on an arbor in quantities based on 4X the diameter of the bore, divided by the face width of the part, to determine the number of parts/load. Young explains that lack of good parallelism and perpendicularity can introduce lead error when cutting the gear, or force a reduction in the number of blanks on the arbor, eroding production efficiency. Pump gears often have a standard keyway or a blind-hole keyway added that must align with a tooth. "When we cut that keyway, it throws up a tiny burr, so honing for final size allows us to clean up that burr, too," he says. "This is where honing really shines, allowing us to control final size automatically down to a few microns. This kind of control is a real advantage when working to high  $C_{pk}$  requirements."

### Processing options

Depending on the requirements for a specific gear, Forest City hones gear bores at various points in the manufacturing process, working with three different Sunnen systems. Parts are typically honed after hobbing, but on extremely tight-tolerance gears, blanks might be honed before and after hobbing. Fixturing on the hones allows some degree of control and correction of perpendicularity, should that be needed. If parts are heat treated, they are honed afterward to correct for the slight shrinkage in bore size. "If there is a plating operation, we have found it is easier to hone a little plating out of the bore than it is to mask the part for plating," Young says.

Forest City Gear uses CBN and aluminum oxide honing tools in several different configurations, depending on whether the bore is blind, keyed, etc. A tool life of about 250,000 parts is typical, depending on the material. Stock removal is usually 0.0020-0.0030 inch (0.05 - (continued)



0.076 mm) at cycle times of 15 seconds. In terms of finish, the hones can achieve a 16  $\mu$ in or better finish.

"Our newest system is a fully automated Sunnen SV-1005 vertical machine, with a rotary table and automated part handling," Young says. "Using Sunnen's Krossgrinding® tools, this machine can control hole size to accuracies of 0.000010 inch (0.25 $\mu$ m), with minimal variability. The machine can even make corrections that are not intuitive for an operator. Switchable control features, such as 'correct for bore shape' allow the

operator to select a 'problem' bore image, for example barrel or taper, and the machine will automatically correct the part."

No matter what the part print specifies, all customers want quieter drives, smoother operation, greater efficiency and long life, Young concludes. "We strive to give customers a product that is noticeably better than what they would get from a competitor working to the same spec. Honing is one way we add this value without adding significant cost."



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### SUNNEN PRODUCTS COMPANY

St. Louis, MO - USA  
World Headquarters  
Phone 1.314.781.2100  
Fax 1.314.781.2268  
Toll Free 1.800.325.3670  
Email [sunnen@sunnen.com](mailto:sunnen@sunnen.com)  
[www.sunnen.com](http://www.sunnen.com)

### SUNNEN AG

Ennetaach - Switzerland  
Phone +41 71 649 33 33  
Fax +41 71 649 33 34  
Email [sales@sunnen.eu](mailto:sales@sunnen.eu)  
[www.sunnen.eu](http://www.sunnen.eu)

### SUNNEN ITALIA S.R.L.

Arese - Italy  
Phone +39 02 383417 1  
Fax +39 02 38341750  
Email [sunnen@sunnenitalia.com](mailto:sunnen@sunnenitalia.com)  
[www.sunnenitalia.COM](http://www.sunnenitalia.COM)

### SUNNEN SAS

Saclay - France  
Phone +33 1 69 30 0000  
Fax +33 1 69 30 1111  
Email [info@sunnen.fr](mailto:info@sunnen.fr)  
[www.sunnen.fr](http://www.sunnen.fr)

### SUNNEN BENELUX BVBA

Kontich - Belgium  
Phone +32 3 880 28 00  
Fax +32 3 844 39 01  
Email [info@sunnen.be](mailto:info@sunnen.be)  
[www.sunnen.be](http://www.sunnen.be)

### SUNNEN PRODUCTS LTD.

Hempstead Herts - United Kingdom  
Phone +44 1442 393939  
Fax +44 1442 391212  
Email [hemel@sunnen.co.uk](mailto:hemel@sunnen.co.uk)  
[www.sunnen.co.uk](http://www.sunnen.co.uk)

### SUNNEN DO BRASIL LTDA.

São Paulo - Brasil  
Phone +55 11 4177 3824  
Fax +55 11 4362 3083  
Email [sunnen@sunnen.com.br](mailto:sunnen@sunnen.com.br)  
[www.sunnen.com.br](http://www.sunnen.com.br)

### SUNNEN POLSKA SP. Z.O.O.

Warszawa - Poland  
Phone +48 22 814 34 29  
Fax +48 22 814 34 28  
Email [sunnen@sunnen.pl](mailto:sunnen@sunnen.pl)  
[www.sunnen.pl](http://www.sunnen.pl)

### SUNNEN RUS LLC

Moscow - Russia  
Phone +7 495 258 43 43  
Fax +7 495 258 91 75  
Email [sunnen@sunnen-russia.ru](mailto:sunnen@sunnen-russia.ru)  
[www.sunnen.ru](http://www.sunnen.ru)

### SUNNEN S.R.O

Strakonice - Czech Republic  
Phone +420 383 376 317  
Fax +420 383 376 316  
Email [sunnen@sunnen.cz](mailto:sunnen@sunnen.cz)  
[www.sunnen.cz](http://www.sunnen.cz)

### SHANGHAI SUNNEN MECHANICAL CO. LTD.

Shanghai - China  
Phone +86 21 58133990  
Fax +86 21 58132299  
Email [shsunnen@sunnensh.com](mailto:shsunnen@sunnensh.com)  
[www.sunnensh.com](http://www.sunnensh.com)

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