

# The "Hole" Story on Gear Quality



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 said. "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", except for worms (5") and worm gears (16"). 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 produce gears for several motorcycles and racecars, as well as one of the few bait 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.

## The Choice tohone

Forest City Gear has used honing since the inception of its business. Young said 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") bores and low L/D ratios (0.5:1), but our range of work includes smaller diameters and relatively deep bores," he said. "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 said. 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 stay tight 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 said: "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



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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 Cpk Holemaking

When working to high Cpk 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 a high Cpk requirement means the band of variability around target values has to be reduced, Young said.

"For rule-of-thumb purposes, when the target is 1.33 Cpk, we shoot for about 60% of the print tolerance; at 1.67 Cpk, the target is 40% of tolerance," he said. "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 Cpk 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. In fact, we have run capability studies where we've hit double-digit Cpk 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" for parallelism and perpendicularity, and the shop can work to tighter tolerances as gear quality dictates.

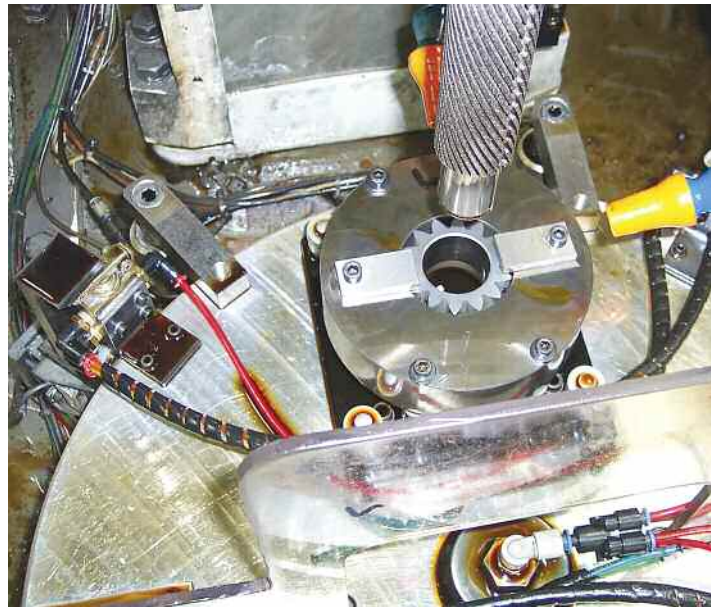
The pump gear blanks are double-disc ground for face parallelism and width, then rebored on an automated lathe to re-qualify the perpendicularity. Some stock is intentionally left in the bore so that final ID size and finish can be set on a hone.

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 said 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 said. "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 Cpk 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 said.

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" at cycle times of 15 seconds. In terms of finish, the hones can achieve a 16 µin or better finish.

"Our newest system is a fully automated Sunnen SV-1005 vertical machine, with a rotary table and automated part handling," Young said. "Using Sunnen's Krossgrinding tools, this machine can control hole size to accuracies of 0.25µm (0.000010"), 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 said. "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."

For more information contact:

Bob Davis  
Corporate Communications Mgr.  
Sunnen Products Company  
7910 Manchester Ave.  
St. Louis, MO 63143  
314-781-2110  
www.sunnen.com  
E-mail: bdavis@sunnen.com