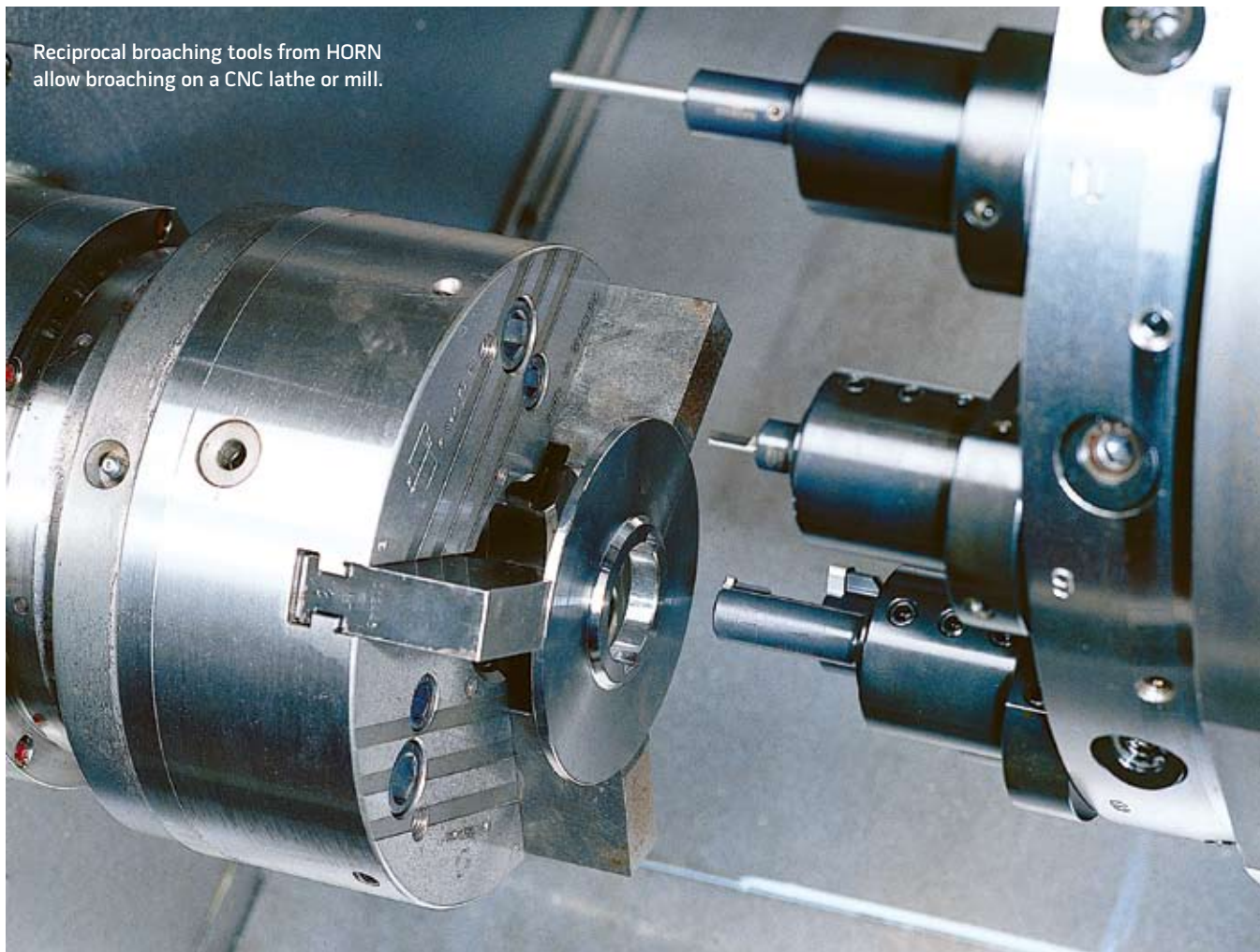


Reciprocal broaching tools from HORN allow broaching on a CNC lathe or mill.



HORN

# Bantam Broaching

Manufacturers use broaching to make small parts for medical and aerospace applications.

By Victor M. Cassidy

**B**roaching is an effective way to make small parts, often for medical and aerospace applications. But the broaches themselves must be carefully crafted to work in these demanding applications. In this article, a number of broaching experts discuss the best ways to broach small parts, the tools and machinery needed to create these parts, and recent innovations that make broaching more productive.

In broaching, a single piece or set of hardened tool steel called a broach is pushed or pulled inside or outside a workpiece to cut a shape in or on it. The

multiple-point broaching tool has progressively taller cutting points, or teeth. As the broach engages the workpiece, each tooth removes a small amount of metal and the succession of teeth takes off the desired amount.

Broaches are typically made of HSS, including M-2, M-3; several grades of powdered steel, such as P/M M4 and P/M T15; and solid carbide. Coatings increase the tools' surface hardness, lubricity and wear resistance.

The broach is supported by fixtures such as broach holders or the broach horns used in keyway broaching. Specialized broaching machines, which are

usually hydraulic, may have rams to push the broach into the part. Some broaching is also done with attachments on standard machine tools.

A hole in the center of a part can be broached to create a profile, or a noncircular shape, such as a square, oval, keyway, serration or D-shape. Broaching can also cut internal and external forms, such as involutes, on gears and splines. Splines may be used to prevent rotation as they hold a drive shaft. Broaching is also used to make slots, notches and rack teeth. Broaching is used in manufacturing products such as rifle barrels, jet engine turbines and space shuttle engines.

## Focus on Small Parts

Many broaches are specials for making small parts. “The customer gives us an application, and we design a broach tool and process to meet it,” said Ken Nemec, president of broach machine and tool manufacturer American Broach & Machine Co., Ann Arbor, Mich. “For us, a small diameter tool would have a minimum diameter of 0.060”.

“For a slot or a surface broach tool, about a 0.02”-thick finished slot would be the thinnest we would consider, depending on the application,” he continued. “We sometimes entertain teardrops or radiuses on slot ends, like you see on hydraulic pump bearings.”

Duane Drape, national sales manager for toolmaker HORN USA Inc., Franklin, Tenn., agreed that broach making is application specific. The toolmaker produces standard and special reciprocal broaching inserts for a CNC mill or lathe that are able to broach forms into bores as small as 2mm. “If the form is substantially smaller, then a laser process would be necessary,” Drape said. “We have to put chipbreakers onto some of our made-to-order PCD- and CBN-tipped carbide inserts. To do that, we use a laser process, which accomplishes the same thing as broaching.”

HORN also manufactures special indexable-insert broaches for dedicated broaching machines.

Peter Bagwell, mechanical engineer for rotary broaching manufacturer Slater Tools Inc., Clinton Township, Mich., said Slater recently had an order for a 0.028” internal hex and a 1/16” external hex. To fill the order, Slater supplied two types of broaches and two types of broach holders. “As far as we know,”

Bagwell said, “these are the smallest broaches being made in the industry.” He added that the functional characteristics of Slater’s rotary broaches are the same at different dimensions, but different speeds and feeds and thrust pounds may be required. “In general,” he said, “the smaller you get, the slower you go.” Depending on the broach size and the workpiece material, speeds and feeds slow as the part gets smaller.

According to Scott Laprade, sales and marketing manager for Genevieve



High Point Precision Products

Example of a small titanium part that High Point Precision Products has broached. The part is next to the side of a penny.

Swiss Industries Inc., Westfield, Mass., broaching small parts means generating a profile that’s under 0.0080”. He noted that usually when rotary broaching, the end user can successfully generate a profile that’s 1 to 1.5 diameters deep.

“As long as the tool is ground accurately, you’ll be able to produce the profiles as you get smaller,” Laprade said. One possible problem is “inertial resistance when the part is so small that it’s not able to rotate the broach holder successfully. Without the rotating motion of the tool, you don’t get the profile generated.” Sinker EDMing is the only

alternative to broaching for small profiles that Laprade knows of.

Marc Stipo, COO for High Point Precision Products Inc., Sussex, N.J., a manufacturer of precision parts, agreed with Laprade that a profile can be generated 1 to 1.5 diameters deep. “When you get much deeper than that,” he added, “you can risk snapping the broach with an axial push because the relief on the broach will weaken the neck. You can create too much torque.”

Russell Roschman is president of VW Broaching Service Inc., a Chicago job shop that broaches parts in a variety of sizes. “For us, the advantage of broaching smaller parts is that we use smaller machines,” he said. The disadvantage is that the tolerances usually don’t change and remain tight. As the part gets smaller, the relative difference between the tolerances available to VW Broaching and the tolerances that are available in the company’s machinery becomes more pronounced. Though he can run small parts faster, Roschman said he must keep a close watch on clamping and tolerances.

## The Only Way?

Often broaching is used because it’s “the only process that is physically capable of producing the format or feature that a customer wants in a part,” said HORN’s Drape.

For example, Boeing wanted to machine a blind-hole in the end of a fuel pump driveshaft for a jet fighter. Broaching was the only feasible process, American Broach’s Nemec said.

“It’s very difficult to beat broaching for speed, accuracy, repeatability and low cost per part when you have a high

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## What’s rotary broaching?

**ROTARY, OR WOBBLE, BROACHING** is used to make internal and external polygon forms on the end of a workpiece while it is rotating. The entire operation takes seconds and is capable of achieving tolerances of 0.0005” and tighter. Unlike conventional broaching, in which polygon forms that increase in size are pushed through a hole until the desired form is achieved, the rotary broach cuts the form in a single pass. Rotary broaching may be used on CNC machines, Swiss-style machines or manual screw machines or lathes.

The rotary broach holder incorporates an internal live spindle that holds the tool at a 1° angle. The spindle spins freely within

the holder and is driven by contact with the rotating workpiece. While the workpiece is rotating, pressure on each corner of the broach is constantly changing. This creates a chisel-type action as the broach is fed through the workpiece to the desired depth. Speeds range up to 2,000 rpm. Most full-form broaching takes about 10 to 15 seconds.

For a detailed account of broaching processes, including horizontal, vertical, high-speed, blind and spiral, straddle, pot, continuous-chain and multiple-pass broaching, visit VW Broaching’s Web site at [www.vwbroaching.com](http://www.vwbroaching.com).

—V. Cassidy



Slater Tools

Tools for micro rotary broaching are available from Slater Tools.

volume of parts," Nemec stated. But broaching of parts at any size makes little sense when production volumes are low or there's a lot of changeover in the manufacturing process. In those cases, the job may be done on a small, manual, hydraulic C-frame broaching press if the end user cannot efficiently machine the desired feature without broaching.

American Broach recently designed and produced a broaching machine that has a programmable logic controller and can change its own setup when the part is on the incoming conveyor using cameras to identify a part and a robot or rotary table to orientate each part correctly. This allows broaching of one-offs when the total number of one-offs is high and eliminates changeover between parts, which truly automates small-lot broaching of any size part, Nemec explained.

#### 'No-Brainer'

Laprade said his Swiss-style and ro-

tary broaching tools often have profiles under 0.100". Swiss-style broaching was "designed specifically for small parts manufacturing, so Swiss machines are generally accurate to  $\pm 0.0002$ ," he said. "Having a Swiss-style rotary broaching attachment in your machine is a no-brainer" when you make very small profiles.

HORN's Drape explained that a shop can do reciprocal broaching on a CNC lathe or a CNC mill. "You're nibbling the material out," he said, adding that a reciprocal broach removes about 0.002" to 0.004" of stock per pass rather than broaching a form in one pass.

"An alternative is the standard broaching machine using a broach with many teeth where each tooth sequentially takes a different cut," Drape said. "When the next tooth comes in, it's removing the 0.001" to 0.004" of stock, but it just feeds through in one pass." In effect, reciprocal broaching on a CNC lathe

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or mill and conventional broaching on a dedicated broaching machine "do the same thing," he said. "There's no difference in the net effect with traditional broaching and reciprocal broaching." Drape added that rotary broaching is another technique used to make polygons, torques, squares, hexes and similar profiles (See sidebar on page 84).

American Broach supplies standard broaching tools for standard machines, but not rotary or Swiss-style tools. "When you're talking about small parts broaching," Nemec stated, "all we do is downsize the application."

He said American Broach specializes in turnkey custom machines for companies with specialized, high-volume

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broaching applications for large and small parts. American Broach designs and builds the machine, installs it and trains the operators. "A lot of people think of broaching as a black art," Nemec said. "It's applied physics. Many different things come together and are interwoven to impact the results. We need to know lots of process information, including the part material specifications, desired surface finish, tolerance requirement and hardness. With this information and a few other customer preference questions, American Broach calculates tonnage, force, coolant and the geometry of the broach cutting tool in order to produce the part in the most cost-effective way."

Regardless of the machine that a shop uses, there's "quite a bit of art" to broaching, said High Point's Stipo. "You can figure out a process on one part and it works—and you can have that exact same geometry on a different material and it does not work."

"You encounter many different vari-

ables as parts get smaller," Stipo added. Coolant, air pressure and chips all have to go somewhere and "the smaller you get, the less room you have." An operator doesn't have much "wobble room" when he is broaching a 0.050" hole. A concentric hole with a consistent diameter is key to broaching a high-quality profile.

VW Broaching's Roschman calls broaching "more magic than it is method." The craftsmen who design and make broaching tools are "really valuable and, unfortunately, a dying breed," he said.




Broaching serves every industry, but a sizable number of small parts are used in medical and aerospace applications. Laprade has seen some defense work, too. Bagwell said small broached parts are typically made of steel, but also may be made of stainless steel, titanium, carbon fiber and nylon. Nemec has done "a little bit" of business with Parker Hannifin Corp., Cleveland, which, for example, needed tiny slits in a small

valve body casting. "More and more car transmission makers are broaching gears and then rebroaching after heat treatment because the quality must be better," he added.

### The Future

Opinions about the future of broaching as a metalworking application in the U.S. varied. Roschman predicted that broaching will decline. "There will always be a place for broaching, because it is very efficient for cutting internal shapes and forms. But eventually technology will do its best to engineer around broaching." He sees broaching as a "very slow" process and expects that substitute technology will appear in 10 to 20 years. Such a development would probably mean "advances in EDM, powder metals, waterjet cutting, perhaps, and stamping ... I'm not sure." Right now, "there's nothing that can do what broaching does, but a lot of processes are barking at its heels."

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Reciprocating broaching tools from HORN remove about 0.002" to 0.004" of stock per pass rather than broaching a form in one pass.

coating company offers nanocoatings that reportedly address the heat generated in most broaching applications and stop heat-related wear by providing lubricity. Especially in small parts broaching, said Nemeč, "the lubricity that the coating provides by sealing all the grains at the top of the broach tool as it's going through [the part] improves the quality of the cut, the life of the tool and the number of pieces you get per tool."

Broaching can be viewed as a mature technology, but maturity doesn't mean the end of all development. Today, machine builders and shops are adapting the technology to smaller and smaller parts—and selling those parts to growing markets. This old dog of a process is learning new tricks. CTE

ing have been declining for some time, said Roschman. He's diversified his firm into shaping, wire EDMing and cutting tool manufacturing. None of Roschman's current customers holds more than 2 percent of his sales volume.

Stipo's much more enthusiastic about broaching. "Machining is heading toward the more micro field," he said. Over the past year or so, he's had success with Genevieve's 2150 series broaching head attachment, which he said excels at profiles under 0.080". Stipo purchased the attachment for his first broaching application involving small parts and has since "gone as small as 1mm in titanium and broached a torx head with the points measuring at about 0.0085" to 0.0090" in titanium also." In addition to this, he's broached small parts made of A-2 tool steel, 17-4PH, 316 and 304 stainless.

"It took us a long time to get the process down," he said, "but having the correct tooling is half the battle. The other half is using finesse to fine-tune everything to get the results you want. Once you have that, it repeats time and time again."

Meanwhile, Drape said HORN has a new product in the offing: broaching attachments powered by a live tool position on a lathe to boost productivity. On many conventional lathes, he said, there's a controlled feed limit of up to 250 ipm, but the new attachment makes feeds of up to 1,420 ipm possible. The product is scheduled to be available the third quarter of 2008.

Nemeč described new broaching tool steels and coatings American Broach & Machine recommends to customers. Böhler-Uddeholm, an Austrian firm, has redesigned powdered steel with finer grains that deliver an average of 15 percent longer tool life. "There's no difference in the grinding or heat treating," Nemeč stated. "As I understand it, it's simply that the grains are finer."

Nemeč recommended specialty coatings from Oerlikon Balzers Coating USA Inc., Elgin, Ill., on his firm's tools. The

**About the Author:** Victor M. Cassidy is a Chicago-based freelance writer.

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