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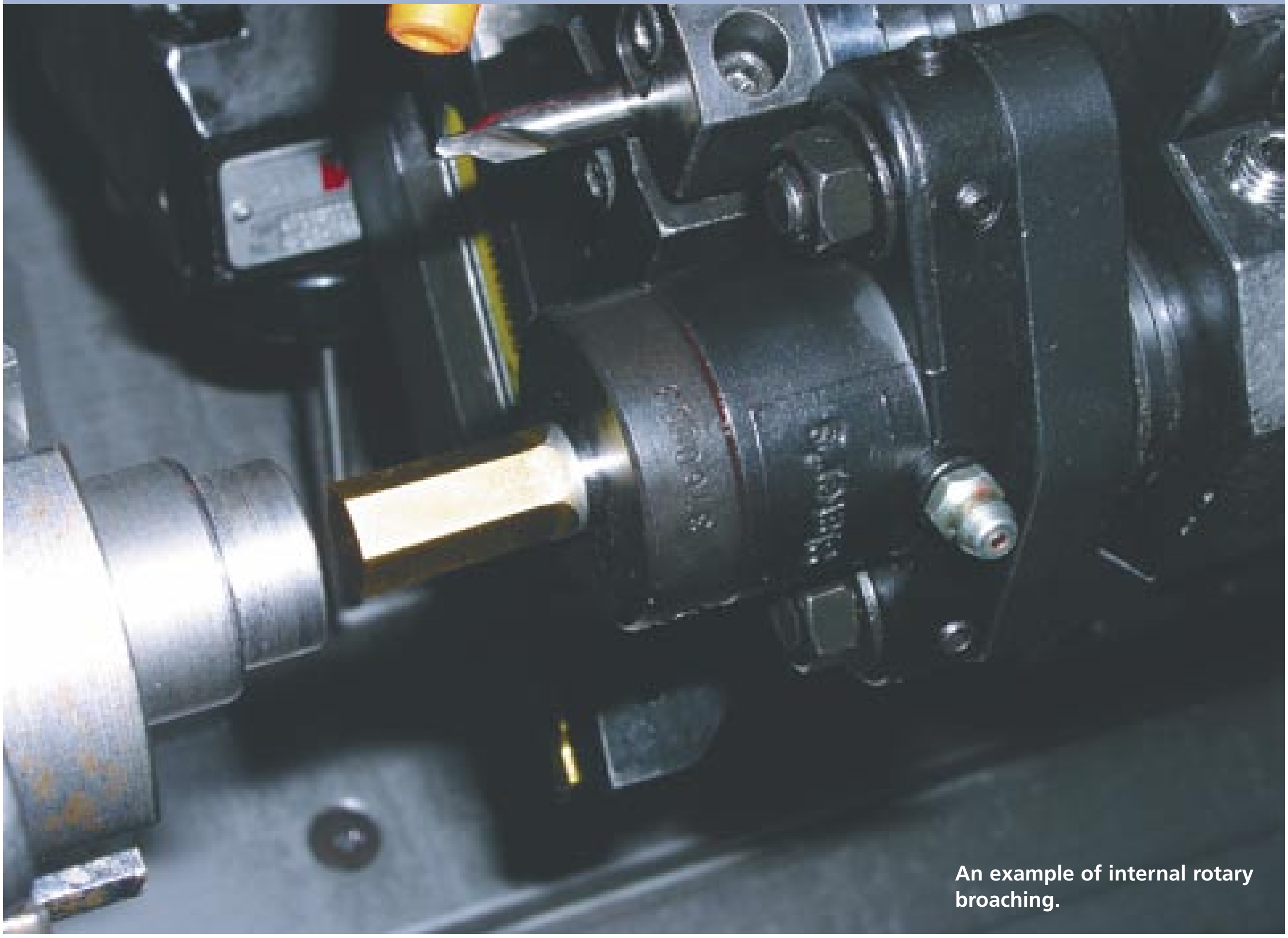
➤BY PETER BAGWELL AND JEFF TRYLES, SLATER TOOLS INC.



An example of internal rotary broaching.

All images: Slater Tools

One-Pass Polygons

With rotary broaching, a polygon form is cut in one pass.

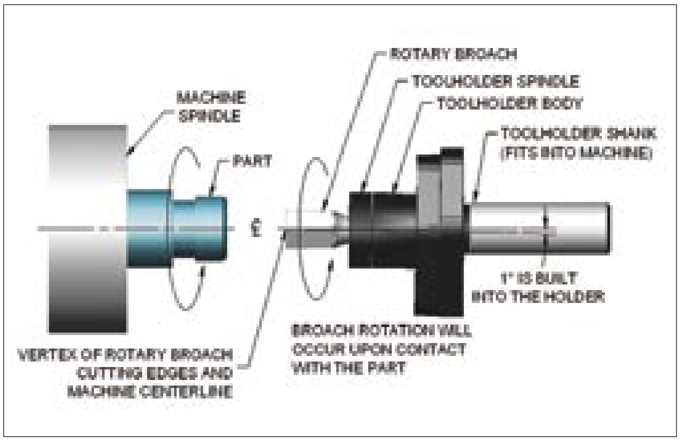
Rotary broaching is a fast and accurate method of producing internal and external polygon forms on the end of a workpiece while it is rotating. The entire operation takes seconds and is capable of producing forms to an accuracy of better than 0.0005".

The advantage of performing this operation is that it almost always costs less, because it eliminates a secondary operation on another machine. In some cases, rotary broaching can be performed at the same time as other operations, thereby increasing speed and profitability during production, without sacrificing accuracy.

Unlike conventional broaching, in which a series of polygon forms that increase in size are pushed through a hole until the desired form is achieved, the rotary broach cuts the full form, one corner at a time, in one pass.

Rotary broaching requires two components: a toolholder and a broach. Due to the increased use of titanium and other difficult-to-machine workpiece materials for items such as bone screws, the variety of materials used to produce rotary broaches has expanded. Standard broaches typically are made from M-2 HSS, but are also available in PM-4 and cobalt-HSS metals like T-15. Broaches are coated with TiN, TiCN and TiAlN to enhance their performance.

Rotary broaching is becoming increasingly popular in the medical, aerospace, automotive and plumbing industries. Due to the large variety of rotary broaches and holders available off the shelf, the process is practical for small machine shops. By simply switching broaches, they can run a different polygon form with minimal, or no, setup change.



Depiction of internal rotary broaching.

Toolholder Design

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. Thus, while 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. Because speeds are up to 2,000 rpm, most full-form broaching takes approximately 10 to 15 seconds.

The holder is designed for use on any CNC machine and can be operated one of two ways. In a turning or screw machine, the holder is stationary. Its internal live spindle and the broach rotate with, and are driven by, the workpiece rotation. Because the broach is workpiece-driven, rotating synchronizing devices are not needed. Therefore, it is possible to rotary-broach at any desired station inside the machine.

In a milling or drilling machine, the toolholder is mounted in, and rotates with, the machine spindle while its free-moving internal live spindle and the broach remain in contact with the workpiece. This moves the holder around the centerline of the hole at a 1° angle, creating the effect that it is "wobbling." Although the holder continues to hold the broach with great precision, rotary broaching is often referred to as "wobble broaching" for this reason.

Finding Form

Form sizes up to 2" can be broached in aluminum, 1½" in brass and 1" in steel. Rotary broaching is best utilized to create small forms at shallow depths. The practical forming length, or depth, for rotary broaching is up to 1.5 times the smallest diameter of the form to be broached.

Hexagons and squares are the most common configurations. Off-the-shelf tools for these forms are available in most sizes. Broaching a hexagon form into a cap screw is a typical application. Profiles such as serrations, splines, six-lobe shapes and other polygon forms can be easily produced as well.

Toolholding Tips

The cutting edge of the broach must be concentric to the toolholder's internal live spindle and its shank. They can easily be aligned using a V-block and some adhesive tape.

Place a broach in the holder and measure how far the cutting edge extends from it. Then, replace the broach with a setting plug (or drill rod the same diameter as the shank) that extends from the holder the same, or a greater, distance than the broach did. Fasten the holder into a V-block. Tape the spindle to the holder body so it doesn't freely spin and then rotate the entire assembly by hand. Adjust the holder until the setting plug zeros at the same distance from the holder as the cutting edge of the broach. Replace the setting plug with the broach and the holder is now ready to be mounted in the machine.

One nice feature of rotary broaches is that, once set up, they cut equally as well in right-hand or left-hand operations.

Pilot Holes and Chamfers

For internal rotary broaching, a pilot hole with a lead chamfer is required. Start with a clean, true-running pilot hole that's as large as the design allows. The hole diameter should be, at a minimum, equal in size to the distance across the flats or inscribed-circle diameter of the form to be broached. The lead chamfer diameter must be slightly

An example of external rotary broaching.

larger than the form being broached.

Except in cases where the spindle can be slowed to a near stop, a minor skid mark is likely to show at the point where the broach makes initial contact with the workpiece. If objectionable, this can be removed by rechamfering the hole. In every instance, a lead chamfer larger than the major diameter of the form going to the minor diameter of the form is required.

Square and hexagon holes sometimes are not required to be full form. In these cases, make the pilot hole pilot as large as possible. The less material to be broached, the less thrust will be needed to broach.

The depth of the pilot hole must exceed the depth to be broached. There must be enough room at the bottom of the hole to allow chips to accumulate without excessive packing. Chips can be removed after broaching with either a boring tool or a flat-bottom drill. A recess at the bottom of the hole allows chips to break cleanly. The recess diameter should be larger than the major diameter of the form being broached.

For external rotary broaching, the turned diameter of the workpiece should be smaller than the major diameter of the form being broached. If full form is required, turn the diameter 0.0008" to 0.0015" larger than the full diameter. For starting the external broach on the workpiece, a lead chamfer is required. A 45° chamfer should be smaller than the minor diameter and larger than the major diameter.

Speeds and Fluids

Bearings in the toolholder are designed for normal machine speeds. Therefore, whatever spindle speed other tools are run at should be acceptable for rotary broaching. Normal feed rates should be on the order of 0.004 to 0.008 ipr for brass and other nonferrous materials, and about half that for mild steel. Grades of stainless steel prone to workhardening present special challenges; check with the tool and material suppliers about recommended feeds before assuming broaching is practical. In all materials, the smaller the broach, the lighter the feed should be.

Fluids play a minor role in rotary broaching. Any type of water- or oil-based fluid is acceptable. The chip is a flowing type and the amount of heat generated is minimal.

When internal rotary broaching in blind-holes, fluid should be applied to the broach tip prior to its contacting the workpiece. Fluid should not be directed into the pilot hole. The fluid may be unable to escape, preventing the broach from reaching full depth. Broaches with vent holes are available to alleviate this condition. For external rotary broaching, fluid may be applied prior to the tool engaging the workpiece or continuously during the operation. △

About the Authors

Peter Bagwell is a mechanical engineer and Jeff Tryles is customer service director for Slater Tools Inc., Clinton Township, Mich. For more information about the company's rotary broaching tools and other products, call (586) 465-5000 or visit www.slatertools.com.

Push me, pull me

When it comes to internal broaching of gears, keyways and splines, a broach is typically pulled through the workpiece or, on rare occasions, pushed through.

When pulling the broach, "no matter how perfect the broaching tool is made or the machine is lined up, the tool tends to wander or drift, which produces a lead error in the part," said Ken Nemec, sales and technical director for Broachman LLC, the LeRoy, Mich.-based North American distributor for broaching machines from Stenhøj Hydraulik A/S, Denmark. "It means the resulting spline is not perpendicular to the workpiece."

He added that even a slight angle, or lead error, negatively impacts face runout, which, for broached transmission gears, causes undesirable transmission noise and premature failure.

Push broaching is primarily utilized when manual broaching, where the tool is pushed through the workpiece using a manual press. Pushing has the potential drawback of uncontrolled wandering based on the part's pilot holes and alignment of the forces. This can be difficult or dangerous to perform with slender broaches.

Stenhøj

Stenhøj broaching machines perform internal broaching using a unique push-and-pull arrangement, where the broach is pushed and pulled simultaneously. This balances cutting forces and extends tool life.

When push, or strip, broaching, the broach is pushed through the part and pulled back through it in a semi-automated process. This combines the worst of both worlds, creating the most opportunity for the tool to wander and wear prematurely.

To address the root causes of this wandering characteristic, Stenhøj broaching machines push and pull the broach simultaneously. This is achieved by collet-clamping both ends of the tool and smoothly driving the tool—via pushing and pulling—through the workpiece with inline steady force, provided by a pair of planetary spindles. The collet-clamping system firmly secures the push and pull ends of the tools and rigidly holds them during the broaching process in collet chucks. Using a synchronized electro-mechanical drive, the push and pull collets move simultaneously in the same direction. "The broach is released each time by the collet for tool handoff and part loading via a shuttle loader," Nemec said.

According to Nemec, the result is tighter part tolerances, finer surface finishes and longer tool life—typically 50 percent or more. In one application, a company went from producing 2,500 parts before the broach needed resharpening to 7,500 parts after switching to the Stenhøj machine.

He noted that the end user had a difficult time telling the difference between the tool being removed for resharpening and the one being put in, but the company made an agreement with the broach maker not to broach more than 7,500 parts before resharpening. "If overrun, a broach never really cuts well again," Nemec said.

In addition to the push-and-pull principle, the Stenhøj machines offer other beneficial features.

- The machines have mechanical rather than hydraulic drives. This means the machine mounts directly to the floor and doesn't require a pit, the machine operates "quieter than an office copier," and there's no risk of hydraulic oil seeping onto the shop floor or leaking into and altering the lubricity characteristics of the metalcutting fluid.
- The machines have small footprints, consuming about one-third the floor space as comparable machines.
- The machines minimize noncutting time—changeovers between parts typically take less than 2 minutes.

Those benefits are desirable, but Nemec pointed out that when it comes to part quality, a Stenhøj broaching machine really shines. "With regards to making a gear with virtually no lead error, this machine is perfect."

For more information about Stenhøj broaching machines, call Broachman LLC at (231) 768-5860 or visit www.broachman.com.