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focus: hole finishing

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# REAMING RIGHT

## A guide to reaming holes cost-effectively.

There are usually three objectives when reaming: holding size, imparting the desired finish and achieving the lowest possible cost per hole.

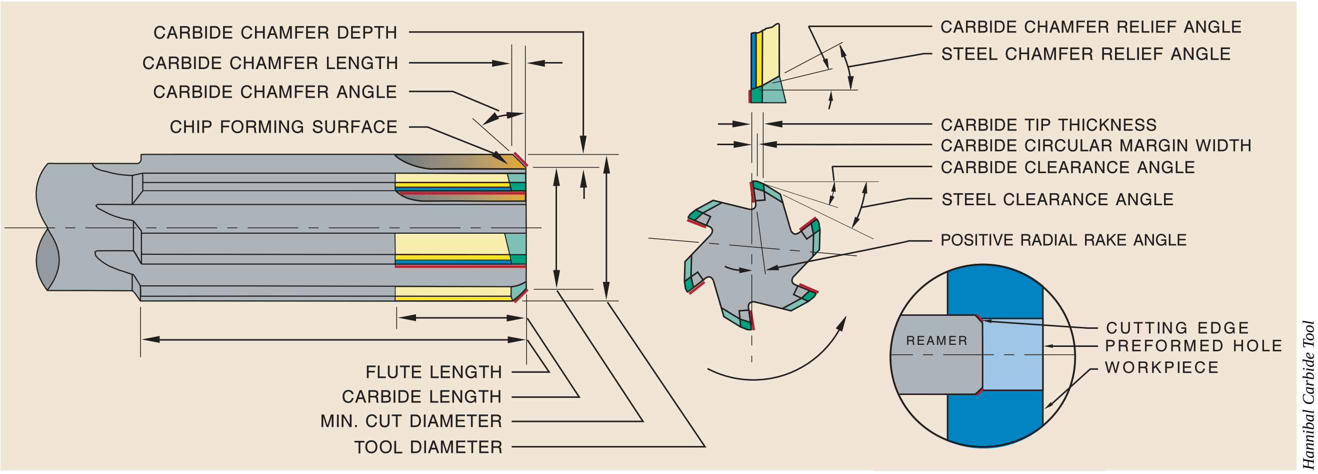
However, many factors warrant consideration to produce quality holes consistently and profitably. This article presents a systematic approach to selecting the proper tool and operational parameters to maximize quality and minimize costs.

Let's begin with an overview of the different reamer materials and styles and the applications for which they are best suited.

**HSS and cobalt-HSS.** Choose HSS or cobalt-HSS reamers for shorter runs of parts made of nonferrous materials and applications where machining conditions restrict the use of harder, more brittle tool substrates. These reamers exhibit lower wear resistance and notably less heat resistance than carbide ones. The maximum working hardness of HSS is about 65 HRC. This modest hardness leaves HSS susceptible to failure traceable to abrasive or chemical wear. These types of reamers are not normally recommended for applications involving hard or abrasive materials, or high cutting speeds.

**Solid carbide and solid-carbide head.** The cutting edge hardness of carbide ranges from 77 to 81 HRC. Carbide reamers are thermally stable and offer high resistance to abrasive wear. Carbide is brittle, however, and rough handling, misuse or misalignment between the reamer and workpiece can lead to broken tools, poor tool life and plenty of aggravation. Solid-carbide tools can be cost-effective when reaming holes up to ⅜" in diameter. Rigid setups and accurate spindles are necessary for optimal performance.

**Carbide tipped.** Carbide-tipped reamers are excellent in long production runs, and their performance really shines when reaming difficult-to-machine and abrasive materials. Small-diameter, carbide-tipped reamers are not as rigid as solid-carbide tools. Carbide-tipped reamers offer the same cutting-edge hardness as solid-carbide tools. Carbide selection




The geometric features of a reamer.

can be based solely on the application, without worrying about strength, because the heat-treated body can take a lot of the bumps and bruises solid carbide can't handle. This tool design is underutilized.

The next step is selecting the flute design best suited to the application. The choices are threefold (Figure 1).

**Straight flute.** The most common flute configuration, straight-flute reamers are best suited for shallow holes in short-chipping materials. This design is capable of reaming good holes in a wide range of materials. However, try to avoid deep holes in long-chipping materials. If the material is abrasive or tough and a carbide-tipped tool is applied, use long carbide reamers for deep holes.

**Right-hand spiral.** This design helps pull the chips up and out of the hole. Right-spiral reamers work well in blind-holes and are useful in bridging interrupted cuts. The aggressiveness of the right spiral flutes may lead to slightly oversized holes, as the reamer actually tries to pull away from the spindle during the cut. It's an effective design for long-chipping materials.

**Left-hand spiral.** These are effective for through-holes, as the spiral flutes tend to push the chips out ahead of the reamer. The action of the left-hand spiral tends to push the reamer back into the spindle, which benefits overall rigidity and provides for accurate control of hole diameter. It is also quite effective in bridging interruptions and reaming hard materials. Left-hand spirals should provide the best size and finish in most materials.

Regardless of the flute design, other tool designs play a significant role.

**Though-coolant.** If the machine has the capability to induce coolant through the tool, use this option. Improved tool life, finer finishes and higher speeds and feeds are all benefits from directing coolant to the chip-forming area. The usual choice for a blind-hole is coolant through the center of the tool, while through-holes benefit more from flute-fed coolant.

In addition, make sure the coolant being used is recommended for the material and application. Also check the mix to be sure it is within the manufacturer's recommendations. A slightly

## A clean and clear finish

Heat is generated when reaming, but not so much that it melts a metal workpiece. However, that's not the case when reaming holes in acrylic.

"Acrylic tends to melt during machining," said Darrell Freeman, CNC coordinator for Blue-White Industries Ltd. "Acrylic goes all over the place. It moves. It melts. It will grab if the cutting angles are incorrect."

In the worst-case scenario, "It will physically shatter like a piece of glass," he added.

In addition to other product offerings, the Huntington Beach, Calif.-based company machines solid blocks of acrylic to produce variable-area flowmeters, or rotameters. After a tapered meter tube is drilled, an 8"- to 12"-long reamer with a diameter up to 2" finishes the hole. "The trick is the rotameters have to be optically clear when we are done with them," Freeman said.

Because the finished product is a metering device, tolerances are tight, and that means the cutting tool tolerances have to be equally tight. "On the reamer, our tolerances on the lands are within about ±0.0005" end to end," he explained. "Then we have some that are down to 0.0002" to 0.0003"."

Freeman pointed out that this means the primary land's 0.002" to 0.005" width has to be within the specified tolerance for the entire length of the tool.

The special spiral-taper, through-coolant reamers from Gammons Hoaglund Co., Manchester, Conn., have straight flutes and a medium helix angle. The HSS tools are either uncoated or coated with titanium nitride, but only the flutes. "The coating is for lubricity only," Freeman said. "The actual cutting edges are not coated. The edges are polished."

The reamers shear the workpiece to provide the desired polished finish. "The rotameter has to have an optical finish with no visible tool marks," Freeman said. This means the reamers have to have a comparable finish. "The reamers can't have any marks on them at all—no drag marks, no grinder marks, no nothing."

After reaming, Blue-White performs minor polishing on the outside of the instrument. "We don't really touch much of the inside."

Typically, a reamer produces 1,000 to 2,000 parts before a tool is sent back to Gammons Hoaglund for regrinding. "They keep regrinding them until we're out of effective tool length," Freeman said.

Maximizing tool life, though, isn't nearly as important as minimizing workpiece deflection. Freeman said: "Acrylic likes to deflect. You touch it with a cutting tool and the tool pushes it away. It will physically push away and then come back down and try to grab the tool."

—*Alan Richter*

*For additional information about Gammons Hoaglund's reamers and other cutting tools, call (860) 432-0252, or visit www.gammons.com. Contact Blue-White Industries at (714) 893-8529 or visit www.blue-white.com.*

Images: Gammons Hoaglund

**A selection of special reamers.**

## REAMER NOMENCLATURE AND TERMS

***A reamer is a multifluted tool designed to size and finish an existing hole. Presented here are reamer definitions and terms to help end users better understand the process and tool types and features.***

**AXIS**
An imaginary straight line, which forms the centerline of a reamer.

**BACK TAPER**
A slight decrease in diameter, from front to back, over the reamer's flute length.

**CHAMFER**
The angular cutting portion at the cutting end of the reamer.



**CHAMFER ANGLE**
The angle between the axis and the cutting edge of the chamfer.

**CHAMFER LENGTH**
The length of the chamfer measured parallel to the axis at the cutting edge.

**CHAMFER RELIEF ANGLE**
The relief angle at the outer corner of the chamfer. It is measured across the margin portion of the land.

**CIRCULAR MARGIN**
The unrelieved part of the diameter adjacent to the flute faces.

**CLEARANCE**
The space created by the relief behind the margin of a reamer.

**CLEARANCE ANGLE**
The angle directly behind the margin that provides clearance.

**CORE DIAMETER**
The diameter of the largest circle, which does not project into the flutes.

**CUT, LEFT-HAND**
When viewed looking up the shank toward the cutting diameter, the reamer must rotate in a counter-clockwise direction.

**CUT, RIGHT-HAND**
When viewed looking up the shank toward the cutting diameter, the reamer must rotate in a clockwise direction.

**CUTTER SWEEP**
The section removed by the milling cutter or grinding wheel when entering or leaving the flute. Sometimes referred to as flute washout.

**CUTTING EDGE**
The leading edge of the relieved land.

**CUTTING FACE**
The leading side of the relieved land on which the chip is formed.

**EXPANSION REAMERS**
Reamers whose size may be increased by expanding the diameter by means of an expansion screw. These types are designed for regrinding and not for adjusting.

**FLUTE LENGTH**
The length of flute not including the cutter sweep, or flute washout.

**FLUTES**
Longitudinal channels formed in the body of the reamer to provide cutting edges, permit passage of chips and allow cutting fluid to reach the cutting edges.

**FLUTES, SPIRAL**
A flute that is formed in a helical path around the axis of a reamer. It may be either right or left hand. Also called helix flutes.

**FLUTES, STRAIGHT**
A flute that forms a path lying in a straight line.

**HEEL**
The trailing edge of the land.

**HELIX ANGLE**
The angle at which a flute is milled or ground to form a helical path.

**HELIX, LEFT-HAND**
When the flutes twist away from the observer in a counter-clockwise direction when viewed from either end of the reamer.

**HELIX, RIGHT-HAND**
When the flutes twist away from the observer in a clockwise direction when viewed from either end of the reamer.

**IRREGULAR SPACING**
A deliberate variation from uniform spacing of the reamer cutting edges.

**LANDS**
The sections of the reamer body that remain after the flutes are milled or ground.

**LAND WIDTH**
The distance between the leading edge of the land and the heel.

**MARGIN WIDTH**
The distance between the flute face and the primary clearance angle.

**NEGATIVE RAKE**
Ahead of center, it describes a cutting face whose cutting edge lags the surface of the cutting face.

**NOMINAL SIZE**
The designated basic diameter of a reamer.

**OVERALL LENGTH**
The total length of the complete reamer, not including male centers.

**POSITIVE RAKE**
Behind center, it describes a cutting face whose cutting edge leads the surface of the cutting face.

**PRIMARY CLEARANCE**
Clearance located directly behind the margin.

**RELIEF**
The removal of material behind the cutting edge to provide clearance and prevent dragging of the heel.

**RELIEF, FLAT RELIEF**
A relieved surface behind the cutting edge.

**RELIEF, PRIMARY**
The relief directly behind the cutting edge.

**RELIEF, RADIAL**
Relief directly behind the margin. See primary clearance.

**RELIEF, SECONDARY**
An additional relief behind the primary relief, it is sometimes necessary to prevent heel dragging.

**SHANK**
The portion of the reamer by which it is held and driven.

**SHANK, SQUARED**
A round shank having a driving square on the back end.

**SHANK, STRAIGHT SHANK**
A round shank.

**SHANK, TAPER**
A shank made to fit a specific (conical) taper socket.

**SOLID REAMERS**
Those made of one piece of tool material.

**SOLID-CARBIDE HEAD**
Those that have a steel shank and a solid-carbide head brazed together.

**STARTING RADIUS**
A relieved radius at the entering end of a reamer in place of a chamfer.

**TIPPED REAMERS**
Those that have a body of one material with cutting edges of another material, which are brazed or bonded to the reamer body.

*—Hannibal Carbide Tool*


Hannibal Carbide Tool

Figure 1: A straight-flute reamer is best suited for finishing shallow holes in short-chipping materials (top). Center: A reamer with right-hand spiral flutes is effective for blind-holes in long-chipping materials. Bottom: The action of the left-hand spiral flutes tend to push the reamer back into the spindle, which benefits overall rigidity and provides for accurate control of the hole diameter.

higher or lower concentration can change reaming results dramatically.

**Expansion capability.** An expansion reamer is excellent for long production runs involving abrasive workpiece materials. As the reamer wears and loses size, the expansion screw can be turned, causing the diameter to expand. The reamer can then be reground back to its original diameter and resharpened. This should provide like-new performance. If the hole diameter remains in tolerance, but the finish deteriorates, simply resharpen the reamer. This type of reamer should not be considered adjustable, with the ability to ream holes of different diameters.

Adding the proper coating to a reamer can extend tool life and shorten cycle times. It is good practice to test both coated and uncoated tools to achieve a true comparison. Common thin-film coatings are:

**Titanium nitride.** A widely used coating suitable for reaming many materials and applications, TiN offers a balanced combination of hardness, toughness, oxidation resistance and lubricity.

**Titanium carbonitride.** TiCN is a harder and tougher coating than TiN, and it is more lubricious. TiCN is excellent for reaming difficult-to-machine and abrasive materials.

**Titanium aluminum nitride.** TiAlN is characterized by high wear resistance, excellent toughness, good lubricity and high oxidation resistance. TiAlN is gaining acceptance as a reamer coating. It is most effective in abrasive and/or heat-resistant materials.

Optimizing your reaming operation requires some time investment, but it pays off by minimizing cycle time and maximizing tool life.

**Stock removal.** It's recommended that the amount of stock removed by a carbide reamer equal 2 to 3 percent of the tool's diameter. (An HSS reamer can remove smaller amounts of stock.) For example, a 0.500"-dia. carbide reamer should remove 0.010" to 0.015" total stock. If too little stock is left, the tool rubs more than cuts. This leads to excessive heat, a poor finish and premature tool wear. However, any given application may work best by removing more or less stock.

**Toolholders.** Precision collets are the preferred method of holding a straight-shank reamer. This may be done in conjunction with a hydraulic chuck. The combination provides outstanding concentricity between the reamer and the machine spindle. Conventional collet systems are quite capable of fine hole finishing. The key is keeping all components free of chips and dirt and making sure the collet is the correct one to hold the reamer shank diameter. If a taper-shank holder is required, it must be free of burrs and dirt that could interfere with the seating of the reamer in the holder.

**Tool overhang.** Always chuck the reamer with the minimum amount of overhang necessary. Excessive overhang leads to additional reamer runout.

**Checking total indicator runout.** This provides a good feel for how the reamer is running in the spindle. Bring the reamer down near the top of the workpiece. Set up an indicator to pick up the highest point on a land; this would be the circular margin. Turn the spindle by hand and compare the reading of each land. Ideally the maximum runout should be 0.001". If the reamer has excessive runout, remove the reamer from the holder, clean and inspect the collet or holder and replace if necessary. If the runout cannot be managed, a floating holder or running the reamer through a bushing may help.

**Rigid fixturing.** Whether holding the workpiece in a milling vise or a more complex jig or fixture, it is imperative the work be held securely. Movement of the workpiece could cause out-of-tolerance hole diameters, poor finishes and tool breakage.

With these steps completed, it's time to develop optimal speeds and feeds. The tool manufacturer should be able to provide starting-point recommendations. When optimizing the cycle time, remember that a higher feed and lower speed yields faster cycles than a higher speed and lower feed.

**Establishing the feed.** Begin at the manufacturer's recommended feed and the low end of the recommended cutting speed range and ream a couple of holes. If the hole diameter and finish meet or exceed the print spec, increase the feed rate by 0.001 to 0.0015 ipr. Continue to increase the feed until undesirable conditions develop. These include poor finish, the inability to control hole diameter and bellmouthed, tapered or egg-shaped holes.

At this point, return to the previous feed rate; you should be at or near the optimal feed.

**Optimal speed.** With the feed established, increase the speed in increments of 10 to 20 sfm. Like the feed, continue to increase until undesirable conditions develop, then return to the previous setting. It may be necessary to fine-tune these numbers after a couple of runs to maximize tool life.

**Sights and Sounds.** While seeking the optimal speed and feed for your application, look and listen. If the tool squeals upon entering the hole, it may indicate misalignment or a cutting parameter is too high. Examine the chips. Discolored and/or nonuniform chips are also evidence of problems. Check the hole, after reaming, for chatter marks; if present, they could indicate improper stock removal or an incorrect speed and feed.

Out-of-spec holes can be traced to a couple of additional sources:

**Improper sharpening or tool geometry.** The majority of the time, standard geometries can do the job, but there are times when changes are necessary. The key areas of a reamer that may need to be modified are the lead angle, margin width, chamfer clearance, back taper and radial rake. If a solid-carbide or carbide-tipped tool is being applied, a different carbide grade may help improve tool performance.

**Material changes.** Cast materials are often inconsistent. Hard spots, free carbides and scale can lead to inconsistent tool life, poor finish and an out-of-spec diameter. A heat treatment that varies even a few hardness points can dramatically alter tool performance. Often, material is the last thing to be considered but is the cause of many problems.

It would be wishful thinking to believe every reamer chucked in a spindle is going to perform as expected every time. Problems do occur, and some are easier to troubleshoot than others. Most reamer problems can be traced back to the areas covered in this article.

The information and guidelines presented in this article have been tried and proven time and again. Nevertheless, there are always exceptions—cases where conventional solutions just don't work. Because theory and reality don't always coincide, experimentation and deviation from the norm may be necessary.

## About the Author

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