AUGUST 2001 / VOLUME 53 / NUMBER 8

BY DAVID FABRY

Up to the Challenge

Small bores present big challenges.

The challenge of boring holes smaller than 0.250" in diameter can cause trepidation—even among experienced machinists. Not only is it nearly impossible to see what is happening inside of the hole, but the required tooling also tends to be fragile.

Additionally, it can be difficult to find the right tool. A machinist is often required to make a tool to suit a particular job. Some manufacturers, however, have begun offering insert-style tools specifically designed to bore small-diameter holes—even holes as small as 0.040" in diameter.

With proper tool centering, the right speed and feed, adequate chip evacuation and a stable tool, any small hole can be bored successfully.

Tool Position

The most important step when boring small holes is to properly set the insert on center (Figure 1). A center-height problem is one of the most common causes of tool failure in small-diameter bores.

If the insert is set below center, several things can happen at the cutting edge that adversely affect tool performance. One is that the cutting edge's clearance angle—the primary relief—is reduced relative to the workpiece, causing the insert to contact the bore below the cutting edge.

This, in turn, causes the insert to rub against the material instead of cutting it. Because the insert is no longer cutting, it vibrates, which drives the insert farther below center. When this happens, it is forced deeper into the metal because of the radial sweep of the bore.

As the clearance angle is reduced, the top rake angle increases relative to the workpiece and causes the insert to "grab" the material instead of cutting it. This increases vibration or breaks the tool—a phenomenon that becomes more extreme when boring smaller diameters. It is nearly impossible to correct a vibrating tool set below center.

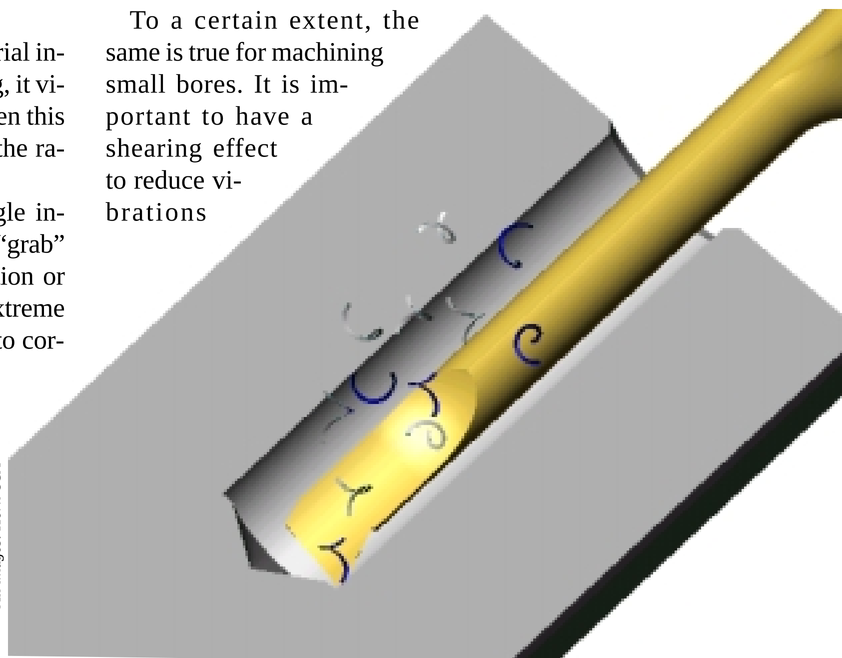
Although setting a tool exactly on center is ideal, it is quite difficult to accomplish in practice. Therefore, it is generally recommended that a tool be set above center, but as close to center as possible. When a tool is set above center, the angular clearance is increased relative to the workpiece, allowing for a freer cutting condition. If vibration occurs, the tool deflects downward, toward center, where ideal cutting conditions occur. It also forces the insert slightly out of the cut, reducing the likelihood of the tool grabbing the material.

In addition, the top rake of the tool is reduced slightly, relative to the workpiece. This generates a small amount of stabilizing tool pressure. If, however, the tool has a flat top rake, this causes a negative cutting condition, which generates too much tool pressure and can lead to tool failure.

For this reason, it is important to apply a tool with a positive top rake. This is essential for machining small bores, especially bore diameters as small as 0.040". This type of insert, while able to bore diameters from 0.040", may only have a diameter of 0.030". Therefore, it is important to generate as little cutting force as possible at the cutting edge.

Let's use shaving as an example. If you were to take an old-fashioned straight razor and hold it exactly perpendicular to your beard, it would take a long time—and be quite painful—to shave your entire face. However, if you were to incline that same razor at an angle, it would cut through your beard easier and cleaner.

To a certain extent, the same is true for machining small bores. It is important to have a shearing effect to reduce vibrations



All images: Horn USA

from the cutting forces acting on a small tool. A good shearing action also results in a better surface finish, regardless of the hole diameter.

Speeds and Feeds

Besides a positive top rake, it is important to minimize cutting-edge forces by maintaining proper speeds and feeds. Standard speeds and feeds can't be applied to bores below 0.250" in diameter. Consider boring a 0.040"-dia. hole at 450 sfm, for example. That would require a whopping spindle speed of 43,000 rpm! Those with high-speed spindles might be able to machine at this speed, but the slightest vibration would destroy the boring tool.

It's more realistic to run at a maximum somewhere around 6,000 rpm. This would result in a much lower cutting speed of 62 sfm. Also, to minimize tool pressure on the small inserts, the DOC should be limited to no more than 0.004" per side. A heavier DOC can cause a 0.030"-dia. tool to deflect and break.

Similarly, generally accepted feed rates—those dictated by the required surface finish and tool-nose radius—are no longer controlled by those factors. To minimize cutting forces, the feed rate should not exceed 0.0005 ipr. At reduced feed rates, surface finish is no longer a concern.

Surprisingly, given that small boring tools cut less aggressively than larger tools, length-to-diameter ratios tend to be greater for smaller tools. Consider again the tool for a 0.040" bore. Since the maximum speed for this tool is approximately 60 sfm and the effective feed is about 3 ipm (0.0005 ipr at 6,000 rpm), tool deflection is minimal. For this reason, the L/D ratio limitation of between 4:1 and 6:1 used for a larger boring bar would be unsuitable.

When making a tool that can bore a 0.040"-dia. hole, the diameter of the tool is slightly less than 0.030"—for trailing-edge and bore-diameter clearance. Standard inserts can bore this diameter up to a length of 0.315". The resulting L/D ratio—over 10:1—is remarkable considering the sizes involved.

Chip Evacuation

Effective chip evacuation is another significant problem when boring small holes. With the tool inside the bore, how do chips escape? When the tool consumes over 60 percent of the bore diameter, even the best-directed flood coolant has a hard time reaching the cutting edge. This restricts chip flow, directs heat into the cutting edge and reduces tool life.

Without coolant, most of the heat enters the tool instead of transferring to the chip. Some manufacturers provide through-coolant inserts or coolant flow along the edge of the insert, which directs coolant where it is needed most. Also, since the coolant flows directly to the cutting edge, it aids in forcing the chips behind the insert and out through the mouth of the bore. This helps to minimize chip packing in the bore and tool breakage.

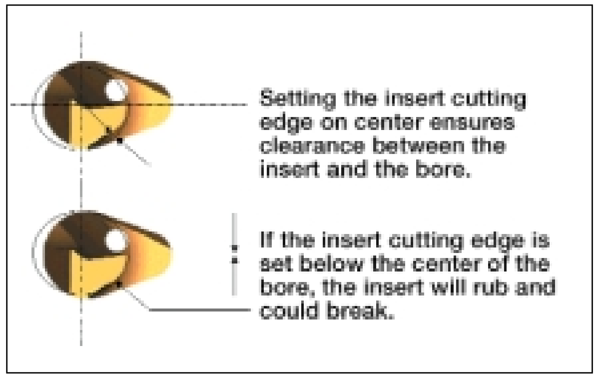
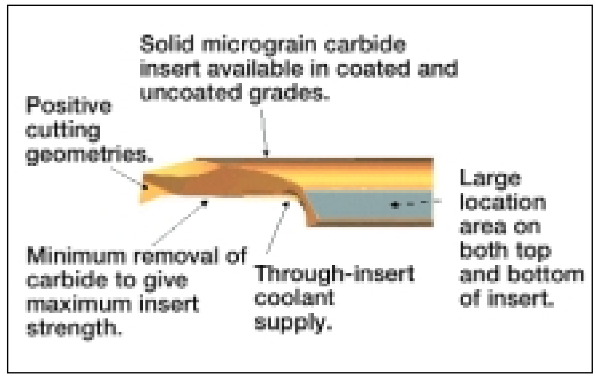


Figure 1



Horn USA's Super-Mini tool is designed for boring holes starting at 0.040" in diameter.

Secure Clamping

To provide quick, easy and repeatable setups, some manufacturers have designed toolholders that prevent inserts from twisting while in the cut. These innovations include insert-clamping flats, inserts with angle-ground back ends and teardrop-shaped inserts.

To understand the advantages of a teardrop-shaped insert compared to a round one, consider the cutting forces involved in external face grooving. (The same type of twisting force exists during internal grooving and boring operations, although to a lesser extent.)

Upon contacting the part, the tool wants to rotate at the same speed as the part. With a round insert, the toolholder setscrew is the only thing that prevents twisting. The teardrop-shaped insert's configuration causes the insert to become "wedged" in the holder, allowing it to resist twisting.

Additionally, the teardrop shape automatically places each insert on center. Imagine trying to find the center height of a 0.030"-dia. tool using a round tool in a collet. If you were to tighten the collet, the tool would twist and end up below center. The way to overcome this is to place the insert above center and hope that the collet is tightened enough to provide sufficient holding power and bring the insert back to center. This is no way to ensure the production of consistent parts.

Boring small holes doesn't need to be a turn-off. Any small hole can be bored by properly setting the center height; providing a positive cutting edge; running at a reduced speed, feed and DOC; flushing out chips with coolant directed at the cutting edge; and holding the insert securely.

About the Author

David Fabry is technical manager at Horn USA Inc. The Franklin, Tenn., company is a subsidiary of Paul Horn GmbH, a European manufacturer of grooving, groove-milling, groove-turning, parting-off and face-grooving products. For additional information about Horn and its products, call (888) 818-HORN, or visit the company's Web site (www.hornusa.com).