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► BY BRAD LEWIS, ASSOCIATE EDITOR

Round Advice

What to consider when drilling convex surfaces.

In the realm of drilling, "tool deflection" is a phrase that fills machinists with dread of off-center holes and part rejections. Therefore, when drilling a convex surface, preventing deflection, or walking, is never far from the machinist's mind.

Although there are a number of ways to handle this problem, some of the solutions may not be cost-effective. For instance, if a machinist is concerned about the drill walking, he could simply spot drill the part to guide the larger tool. However, this solution involves another operation, adding time and increasing the part's cost.

This article examines basic considerations that need to be taken into account when drilling holes in convex surfaces.

Getting the Point

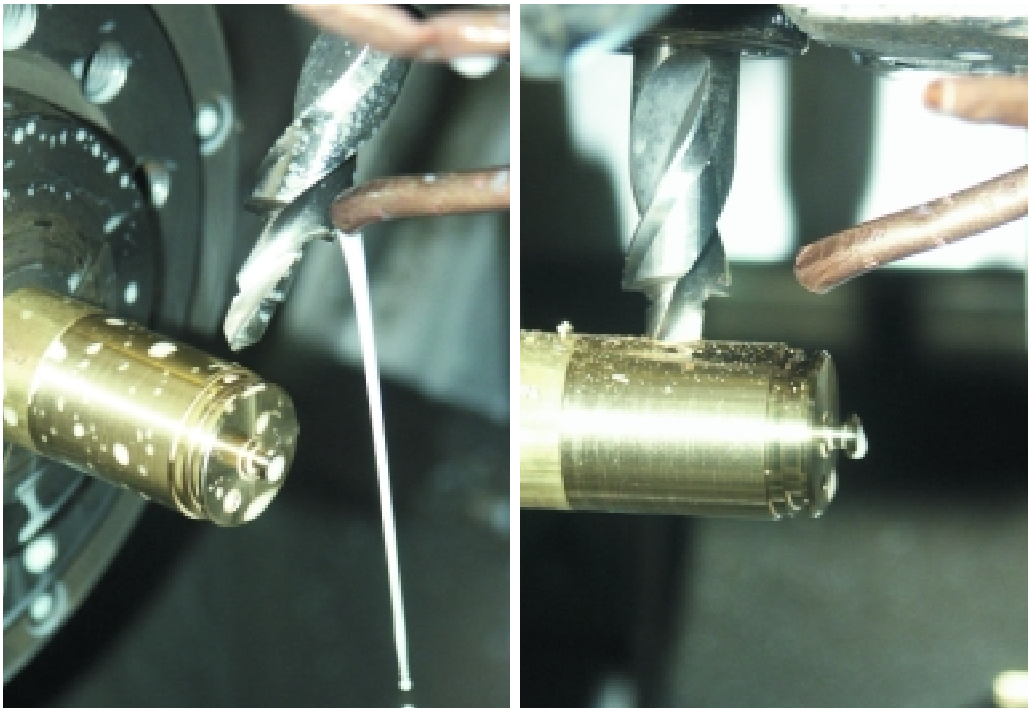
Mike Plankey, technical specialist for Kennametal Inc., Latrobe, Pa., outlined several options for this type of operation. The first is to apply a center drill to put a nick or an indention in the surface, so that the drill has a starting point and the tool is prevented from walking. Another option he mentioned is to use a split-point drill. It's ground so that its cutting lips start cutting immediately upon contacting the workpiece surface, an action that prevents walking.

Jim Geske, senior technical services engineer for Precision Twist Drill Co., Crystal Lake, Ill., said there are at least four self-centering drill points that are effective for convex surfaces: the helical, the Bickford, the four-facet and the split-point.

The Bickford and helical points are similar in that both have a helixed cutting tip on the drill's point. In addition, Geske said, "If you're drilling into thin-walled tubing with tight tolerances, then a Bickford point would probably work better, since it lets you control the burrs that emerge on the other side of the hollow part."

With regard to helical and Bickford drill points, Geske credits the crown height on the tool's chisel for its self-centering capability. "The center of the drill actually contains the web and on the end of that web is the point, where the two cutting lips meet. The chisel actually connects those two cutting lines."

Geske contrasted this design with a conventional drill point, illustrating how the helical point is self-centering: "If you look at the chisel [on a conventional drill point], it would be flat, just like a cold chisel. And if you put a



Left: A step drill prior to entering a convex surface and in the cut.

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chisel on a convex surface and try to start a hole, you're not going to be able to do it. If you look at a helical point on a convex surface, you actually come down on the radius itself. That's what makes it a self-centering point.”

However, the Bickford point, Geske said, is impractical for a solid-carbide drill, because the point is radiused on the corner. Therefore, producing the tool requires about nine different diamond wheels, which would be prohibitively expensive. In that case, Geske said the toolmaker should return to “the helical point, with a 60° or 90° angle added to the outer corner of the tool, which serves the same purpose as the radius corner.”

The four-facet drill point has a similar design to the helical and the Bickford, but it has two primary and two secondary facets that meet at the center of the tip to create a self-centering point. Geske said there are two styles of four-facet points: the four-facet overlap and the four-facet on-center. With the overlap version, the primary facet is about the same thickness at the web, so the primary angle creates the chisel angle on the tool. “Naturally, the higher the relief, the higher the chisel angle will be,” said Geske.

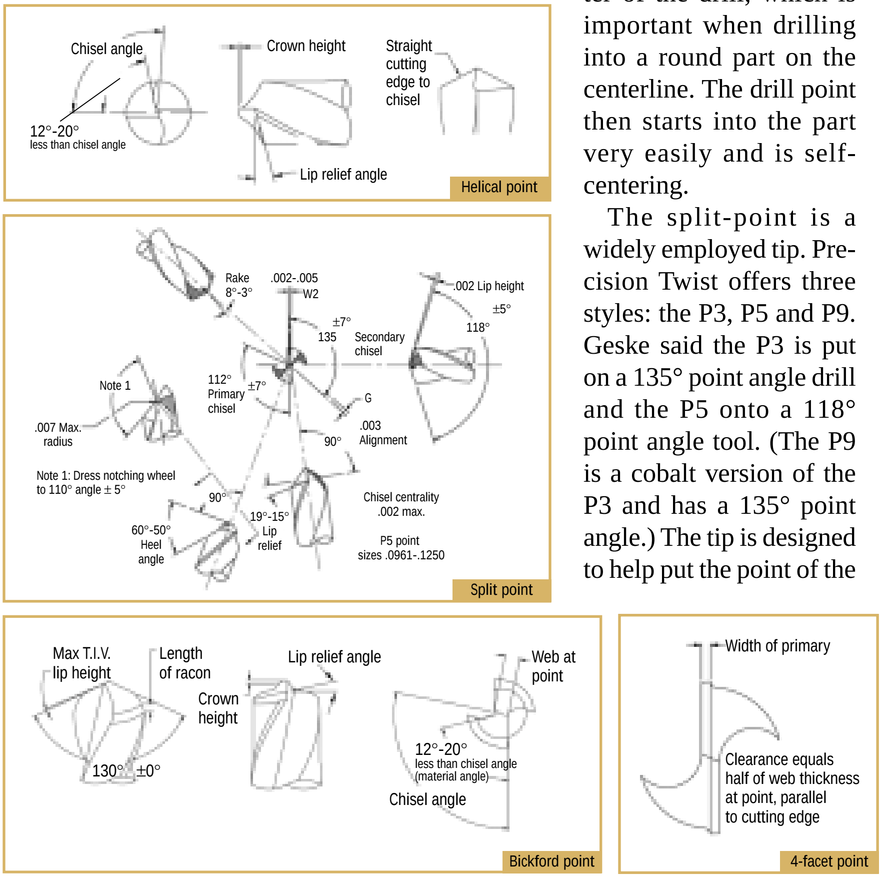
For drilling into convex surfaces, however, he recommends the four-facet, on-center point, because the toolmaker “would want all primary and secondary facets to meet right in the center of the tool, to provide the centering capability.”


CJT Koolcarb Inc.

Drilling into convex and irregular surfaces requires a tool with maximum rigidity.

Don Strubler, vice president of operations for Performedge Inc., Fort Mill, S.C., discussed the benefits of the split-point geometry. On most carbide drills, he said, there's either some sort of split-point geometry or some sort of S-configuration geometry. The split-point relieves the tool pressure at the very center of the drill, which is important when drilling into a round part on the centerline. The drill point then starts into the part very easily and is self-centering.

The split-point is a widely employed tip. Precision Twist offers three styles: the P3, P5 and P9. Geske said the P3 is put on a 135° point angle drill and the P5 onto a 118° point angle tool. (The P9 is a cobalt version of the P3 and has a 135° point angle.) The tip is designed to help put the point of the drill at the desired location on the workpiece. For example, said Geske, “a ¼"- to ½"-dia. drill creates a web thickness in the center of the tool from 0.002" to 0.009" thick. It's that web thickness that makes it self-centering, because the tip comes down to a needle point.”



Precision Twist Drill Co.

Figure 1: Four self-centering drill points.

Echoing the need for a guide point is Al Choiniere, president of Superion Inc., Xenia, Ohio. “Very often we put a dimple point on the drill, making sure the center point makes contact prior to the OD of the drill,” he said. “If the machinist is entering the workpiece with a convex radius of 15°, the drill-point angle has to be greater than that in order for the drill point itself to make contact first.” Otherwise, he added, the machinist would have to use a tool with a flatter point, such as an endmill, and simply mill the surface prior to penetrating it with a drill.

Furthermore, when drilling off-center or on a slant, such as a milled surface with an incline of greater than 6°, Strubler said that the surface ought to be premachined with an endmill.

“When you're over 6°, what happens is instead of the point engaging, you're engaging the inside part of your drill.” This gives rise to tool bounce, he said, “as two flutes start hitting the surface of the workpiece, one flute is going to kick to one side and not center in the hole very well."

According to Geske, the depth of the hole and whether the workpiece is tubular or solid also factors into what style of point is used. "For solid workpieces, you have to consider how deep you're going to be drilling, because that will dictate the style of tooling, whether it's parabolic or conventional," he said. For holes deeper than 4 diameters, he recommends a parabolic drill, a wider-flute tool that allows for faster speeds and greater hole depths.

Tool Design

Once the tool is beneath the surface of the workpiece, the point geometry suddenly takes a backseat to other tool-design considerations, such as chip clearance and rigidity. Tools must not only have the proper point, they must also remain rigid throughout the operation. Almost uniformly, stub-length tools are applied when drilling convex surfaces, particularly in live-tool operations.

Indeed, demand for such tools has risen, according to Tom Trost, vice president of sales for CJT Koolcarb Inc., Carol Stream, Ill., a maker of solid-carbide drills. He said the company's stub-length, solid-carbide, 30 percent web, 140° point, TiN-coated, split-point drills are becoming a commodity item in the market.

As with any drilling operation, chip clearance is a major concern when it comes to the tool's design. To address this issue for 3- to 4-diameter-deep holes, Strubler said most drill manufacturers have widened their tool's flutes.

He added that within the last 5 years, toolmakers have learned how to manipulate grinding wheels and shapes to improve flute forms. As an example of this innovation, he cited the evolution of solid-carbide twist drills.

"For most carbide drills made by major manufacturers, the web of the drill is either parallel or it gets smaller as the drill goes back, so the flute form gets bigger as it goes back toward the shank of the drill," he said. "For high-speed steel drills, it's exactly the opposite. In order to maintain core thickness for the rigidity needed for HSS drills, the web gets thicker and the flute volume gets smaller. So the deeper you drill, the less chip evacuation you have and the more potential problems there are."

Speeds, Feeds and Cooling Down

Although the tool and workpiece materials largely determine the speeds and feeds when drilling, there are some basic rules of thumb to apply when drilling convex surfaces. Strubler emphasized the need to have a slower feed on entry than normal.

But sometimes the operation demands unusual procedures. Strubler recalled a battery manufacturer that machined lathe-turned ram parts used to press powders into cylindrical batteries. In order to feed the drill without stalling the motor, Strubler said the machinist was peck drilling, or repeatedly feeding in and then backing out of the

A Convex Challenge

To see the part-design possibilities that convex-surface drilling can open to a shop looking to produce intricately machined parts, talk to Kazimierz Aleszczyk, president of Wright Technologies, a Rosemont, Ill.-based producer of medical and military parts. His company needed to produce holes in convex surfaces to tight tolerances consistently to meet its contract for supplying brass air valves for respiration machines.

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Parts produced by Wright Technologies.

After the workpiece is roughed, grooved and threaded on a Hardinge CNC lathe, two holes, one ⅝" in diameter and the other ½" in diameter, are side-drilled and tapped in the air valve's major diameter with HSS step drills. The stub-length drills produced holes 3 and 2 diameters deep, respectively.

Since the live-tool turret only has a six-tool capacity, the holes have to be drilled in one pass and then tapped, without adding another tool for spot drilling or any preliminary facing to guide the drill.

According to Aleszczyk, the job presented his company with a number of holemaking issues it had not dealt with previously. "This was a new process for us," he said. Therefore, the company ran comparison tests with different kinds of drills, such as HSS vs. 8-percent-cobalt HSS. Wright discovered that the HSS tools tended to chip and break less often than the cobalt versions. In addition, said Aleszczyk, "With cobalt, we were getting burrs, and if we had to deburr the part, it would be too expensive."

Wright considered going with carbide, but since the cobalt and HSS tests revealed that increased tool flexibility when cutting the brass workpieces led to longer tool life, carbide fell by the wayside.

Using HSS, however, also meant that a copious amount of coolant was required. "We could only use the HSS tools when coolant was applied, otherwise we would get tool burn."

In addition to selecting the proper tool material, Aleszczyk also had to worry about the tool walking on the convex surface. Therefore, tool length became a critical issue. "Even if the live tool is on center," he said, "if the drill is too long, it's going to walk and your hole will be off-center, so we needed a short tool."

For additional information about Wright Technologies, call (847) 671-3353.

hole. This practice, said Strubler, is not good for carbide tools, because when they're retracted, sometimes a portion of the chip is left in the bottom of the hole. And when the carbide goes back in at a higher speed and feed, it hits the chip, which can damage the drill.

To solve this problem, Strubler recommends adding a dwell cycle to the operation. "Rather than pull out of the hole, put a short dwell in the cycle and then let the horsepower of the spindle catch up, then start feeding again," he said.

As far as the right coolant to use, Trost said a lot of machinists who perform these operations use straight oil, but if there are outside influences, such as customer preferences or environmental concerns, an oil-and-water emulsion works well, too. "If you get something with more lubricity in the cut, you make it easier on the spindle, therefore, decreasing the power required and lowering the coefficient of friction."

Clearly, selecting the right tool for convex-surface drilling requires almost as much planning as writing the G codes for the machine's tool path. From selecting the right drill point to choosing the proper flute design and coolant, this operation presents unique challenges for even the most skilled machinist.

Yet for all of the attention to these details, it helps to keep in mind that this is still a drilling operation at heart, where drilling fundamentals still apply.

The following companies contributed to this article:

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