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Farewell to BUE

A new drill point counters built-up edge.

Our January issue contained an interview with Kevin Colvin, who discussed a drill resharpening procedure he developed that became the basis for a newly patented drill ("Talking Points," page 28). We thought his design was so engaging that we decided to tell readers more about it. The following article, written by CTE staff members, contains additional details about the drill culled from a paper Colvin wrote.—Ed.

When a drill removes material, the chisel edge penetrates the material as the cutting lip rotates and the cut material flows up in front of the cutting lip. This shearing action generates heat sufficient to reach the material's plasticity region—often above 1,600° F.

Frictional forces from tool penetration and the material deforming against the cutting tool generate heat. Frictional heat is also generated by contact between the drill's body and the workpiece. This rubbing results from insufficient axial relief or a lack of radial relief. Additionally, these conditions can change due to built-up-edge interference.

During drilling, some of the flowing material welds to the cutting edge. These BUE particles break off sporadically and lodge between the cutting edge and the workpiece. This causes nicks in the tool as it rotates and can damage the part's finish. This condition typically manifests itself as a rough surface. As the BUE interference continues—more rubbing occurs than shearing and tool failure becomes imminent—the tool's cutting ability rapidly degenerates.

With conventional through-coolant drills, centrifugal force acts on the coolant as the tool rotates (Figure 1). Coolant, fed through the drill's point, flows out and floods the work surface. The centrifugal force spins coolant outward and cools the front of the subsequent chip as it is formed by the trailing cutter's tooth. The pressurized coolant keeps the morphizing chip cool as a primary function, then the cutting lip is cooled.

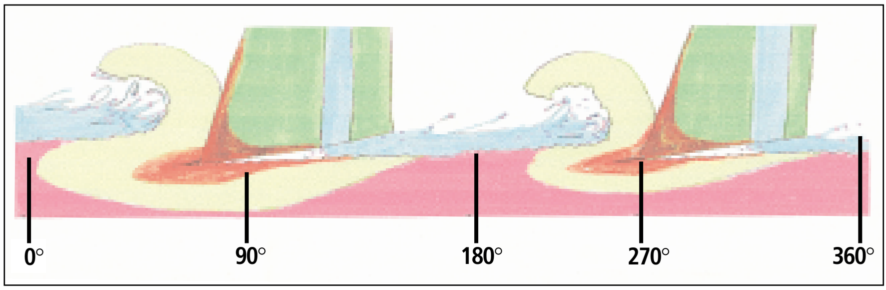
While this method is superior to flooding the cutting zone with coolant and hoping some will find its way down the hole to the tool/workpiece interface, there has not been a way to direct the coolant to the cutting edge.

With a through-coolant drill, friction arises at several areas of the tool simultaneously: the center web region of the drill and the cutting lips. This design weakness leads to the development of excessive heat. And as the heat of friction increases, BUE becomes more prevalent and eventually can cause extensive damage to the tool.

Also, with increased heat, dimensional changes occur. Typically, hole size and surface finish are affected. In some cases, the tool may actually seize in the hole.

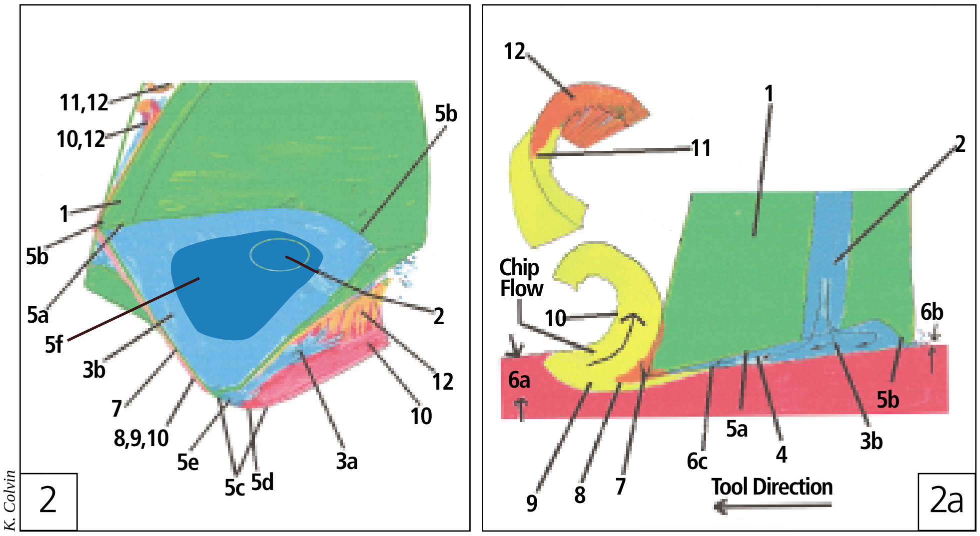
New Geometry

A recently patented drill profile appears to address the issues of excess heat and friction that are generated during drilling. The new geometry is the result of an astute machinist's ability to "read" tool wear patterns and use predetermined feed and speed ratios to generate an improved cutting geometry that he could grind onto drills.



K. Colvin

Figure 1: Coolant flow with a conventional through-coolant drill. Notice the backward flow to the face of the morphizing chip and that coolant is not directed toward the cutting edge.



K. Colvin

Figures 2, 2a: View of the Colvin drill illustrates how the hollowed out chamber and dam retain coolant and direct its flow forward to reduce friction between the workpiece and the tool while flushing BUE out of the path of the cutting lip. Key: 1: Tool (tooth). 2: Coolant hole. 3a: Coolant under centrifugal force. 3b: Coolant under hydraulic force. 4: Thermal dissipation of coolant. 5a: Clearance angle. 5b: Dam. 5c: Web. 5d: Axial center of tool. 5e: Web gash grind (notch). 5f: Concave area. 6a: Depth of cut. 6b: Minimum desired tool clearance. 6c: Most recently cut material. 7: Endomoporphic region—built-up edge. 8: Chip morphology (high-thermal region). 9: Chip morphology (low-thermal region). 10: Morphisizing chip. 11: Chip. 12: Heat dissipation.

The machinist, Kevin Colvin, is a journeyman tool and cutter grinder at a shop in upstate New York. One night, he inadvertently reground HSS drills using a misadjusted setup. He discovered that the drills performed better than those reground the normal way.

Then, over the course of several months, Colvin began adjusting the grinding pattern during subsequent regrinds, extending the tools' wear life a little more each time. Also, he reduced the coolant flow incrementally from where it was not needed and redirected it to the cutting edge, where it reduces friction.

The drill, which Colvin calls the "Pressure Tip Tool," is designed to retain coolant being pumped to the point, as detailed in Figures 2 and 2a. (No photographs of the drill are available.)

A concave area ground on the

The economics: Up 1.4 percent, down $36,948!

At the shop where Kevin Colvin works, one type of drill used is a HSS, TiN-coated, ⅝"-dia. oil-hole drill. Ground with a conventional point, these tools lasted 2,000 drilling cycles before they required resharpening. The feed rate was 0.007 ipr.

Then a drill was ground with Colvin's coolant-retention profile. Negligible tool wear was observed upon reaching the 2,000-hole plateau. A new plateau had to be determined, but to establish the number of appropriate cycles, it was decided that Colvin's drill would stay in service until an out-of-tolerance part was made or when a tool showed a bad wear pattern. Tool life doubled, tripled and then quadrupled. The test drill ran consistently for 16,000 holes.

The tool still had available life, with the last part machined being as good as the first, according to Colvin. Over time, tool life for his drills have proved to be between 12,500 and 48,000 holes. Now, assuming an 8-hour shift and a 2,080-hour shift-year, the following figures suggest significant cost savings and productivity improvements are possible with the drill.

With the shop's 12 machining centers drilling one hole every 9 seconds, the company has a maximum annual shift capacity of 9,818,640 holes. With an expected productive life of 2,000 holes per sharp tip and the tool material to support seven to 10 resharpening cycles, a standard profile drill could be expected to produce 16,000 to 22,000 holes. With the cost of a new drill being in the neighborhood of $85, this translates into a tooling cost between 0.4 to 0.53 cents per hole.

However, the actual shop productivity is less than 9,818,640, because tool changes take time—5 minutes per change in this case. That means for the 3,200-hole capacity per machine per 8-hour shift, and an expected 2,000-hole tool life, a tool will be changed an average of 1.6 times per shift per machine. This translates as a reduction in hole production of 53 holes per shift per machine, or an annual lost capacity of 165,360 holes.

This brings actual annual capacity down to 9,653,280. So based on 9,653,280 holes, the tooling cost for drills is between $38,613 and $51,162 per 2,080-hour year, excluding regrinding costs. If the plant ran three shifts, the tooling budget could be $150,000 or more.

Now, crunching some numbers: When Colvin's new drill profile is factored into the process, the numbers change dramatically. Each drill produces between 12,500 and 48,000 holes. Additionally, because the drills wear less, there is enough tool material to support an average of 40 regrinds—four times the maximum previous level. Using 12,500 holes per ground tip as a lower limit, a single, $85 tool can produce 500,000 holes.

Also, the number of holes not drilled because of tool changes goes from 53 per day per machine to nine. Annualized, this becomes a gain of 137,280 holes, or a 1.4 percent improvement in productivity. Viewing the cost per hole from the same conservative perspective, the $85 drill produces 500,000 holes at a cost of 0.02 cents per hole—5 percent of the previous best cost. Annualized, this means that with the new drill profile that produces a half-million holes, the company should spend about $1,665 per shift-year for its 12 machining centers.

So, let's be conservative and say the Colvin drill profiles saves $36,948 annually ($38,613 - $1,665).

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face of the tip—the curved surface that extends radially from the chisel edge of the web to the circular edge of the flute—serves as a reservoir for coolant. By forming this hollow region with a rear flair to accommodate the tool's feed path, a retention pool is created between the newly machined material and the clearance angle. The hollow region is on the tip of each flute at the coolant hole.

As the drill rotates, the point takes on the characteristics of an impeller in a centrifugal pump. That is, the cutting lips on the front of the flutes and the dams—the result of the ground flair—on the trailing edges of the flutes act like vanes on an impeller. This action retains the majority of the fluid that is trapped between the tool's clearance angle and the newly cut material.

As the drill rotates in the hole, hydraulic forces push the pressurized coolant forward to the cutting edge. At the cutting lip, coolant flows under the cutting edge to reduce friction and the resultant heat. Also, since the coolant is flowing to the cutting edge from behind, it can flush small workhardened material particles forward and away from the cutting edge.

This action serves to evacuate these particles with the cut chip and lower the temperature of the particles. By reducing the amount of BUE interference with the cutting swath, BUE adherence to the machined surface is limited to the underside of the morphizing chips.

Coolant also flows out from the back of the tip, under the dam, to cool the front of the subsequent chip being formed. The remaining heat is borne away with the coolant flow from the cutting zone, exiting through the fluted region with the chips.

Benefits

When applied properly, Colvin said his drill creates a dynamically responsive system that:

- directs coolant to the true cutting edge;
- increases coolant exit velocity where necessary on the tool;
- eliminates critical contact friction;
- reduces cutting zone heat;
- prolongs tool life; and
- enhances drilling accuracy and cylindricity.

The design also aids in the lubrication on the cylindrical sides of the tool's teeth to the full DOC, said Colvin. This also means that it is possible to ream a hole accurately to a dimensional size in one pass.

The biggest benefit of using the drill, however, is its productivity-enhancing capabilities. Colvin reported that the design has saved significant amounts of time and money at the shop where he works (see sidebar on page 46).