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By Bill Kennedy,
Contributing Editor

Put the brakes on micro-endmill breakage

As parts and part features shrink, so do the tools required to machine them. Process factors that are not critical when using macroscale tools literally become make-or-break considerations at the microscale. An inappropriate cutting parameter or toolpath can snap a tiny tool instantly.

That's certainly the case with endmills, one of the most commonly applied microtools. Micro-endmills 0.005" in diameter and smaller operate under their own set of "unbreakable" rules.

Performance Micro Tool

A 0.0004"-dia. endmill from Performance Micro Tool, which is dwarfed by the eye of a ladybug.

Jeff Davis, vice president of engineering for Harvey Tool Co., Rowley, Mass., said the most important factors in controlling microtool breakage are speeds and feeds. "If you don't have the right rpm and feed rate and, therefore, the right chip load, you are going to pop that tool right off the bat."

If the chip load is too small, the tool rubs instead of cuts, wears, heats up and breaks. With too large a chip load, the heavy cutting pressure will snap a microtool. The key is to find the combination of parameters where the tool remains intact and cuts effectively.

In terms of managing chip load, "most of the world is pretty good down to 0.005" in diameter," said Dave Burton, president of Performance Micro Tool, Janesville, Wis. With tools smaller than that, however, "the radius on the cutting edge plays such a big role that it really kind of muddies up the rest of the variables if you don't understand it," he said. "The rake geometry built into these tools is meant to be a shearing, positive rake, and if you take less than the suggested chip load, only a percentage of that tooth bites in and you are [effectively] using a negative angle. You start to wear a radius on the cutting edge and it ends up creating a lot of heat—a lot of rubbing and skipping."

In addition to managing chip load, minimizing runout is crucial to keeping a microtool intact.

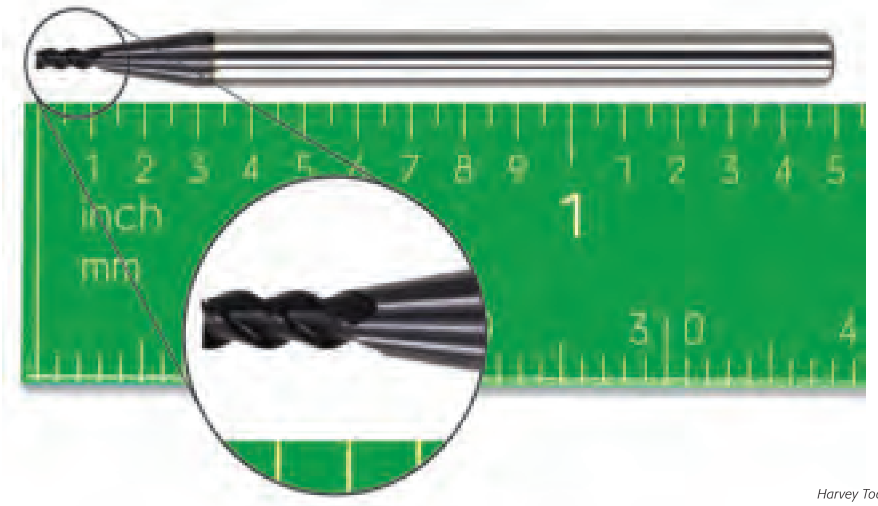
For example, the cutting edge of a 0.010"-dia. endmill may have a radius of 1μm. If it's applied and the chip load is 0.000001", the tool's cutting edge will end up being honed, preventing it from shearing the workpiece material. "The cut might last 0.1" before the thing snaps," Burton said. "At a suggested chip load of 0.0002", you might get 100' of cut. It has to do with whether the tool is cutting the material or the material is cutting the tool."

In addition to managing chip load, minimizing runout is crucial to keeping a microtool intact. A negligible amount of runout for a large tool may represent a significant percentage of a small tool's diameter. "You want to look at the runout of the cutter, the holder and the spindle as an entire system," Davis said. "Even if you have your speeds and feeds dead nuts, if you are running a 1⁄32"- or 1⁄64"-dia. endmill and you've got 0.0003" or 0.0004" runout, you're going to pop that tool."

Davis said shops seeking to minimize runout increasingly employ shrink-fit and hydraulic toolholders and microtools with shanks that meet metric h6 tolerances. While a standard English or ANSI cutting tool shank tolerance would be +0.00/- 0.0005", an h6 tolerance for a tool with a ⅛"-dia. shank (the shank diameter for many microtools) would be +0.00"/-0.00031", Davis explained, and the tighter tolerance maximizes grip and rigidity. (The metric h6 tolerance in this case is converted into inches.)

Runout can be checked statically, with an indicator. For very small tools, though, Burton recommends measuring machine runout dynamically, using noncontact instruments such as the Optec RI.

To protect a delicate microtool, toolpath programming should focus on gradual loading and unloading of cutting pressure. "Basically, with these small tools, you use a very high feed rate but you cut very little material; you don't go very deep," said Hans Liechti, manager of Mikron Corp. Monroe (Conn.)



Harvey Tool

This 0.046"-dia. endmill from Harvey Tool features a variable-helix design, which reduces chatter and harmonics that can break a microtool while also permitting use of higher metal-removal rates than standard micro-endmills.

The machine tool's CNC must be capable of generating rapid back-and-forth tool motion, and the CAM program must anticipate moves into radii and corners to prevent the spindle from overshooting, applying too much pressure and breaking the tool, Liechti said. He added that the key is to maintain a constant feed as the tool moves linearly

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as well as radially. "You keep the same DOC all the time," he said.

Davis noted that, as with macro-milling applications, the climb milling technique is recommended. In climb milling, the cutter teeth enter the work at full DOC, and pressure on the tool is more consistent than in conventional milling.

It is also crucial to minimize vibration, which can shatter a microtool. Workholding should be rigid, and the vibration characteristics of the machine tool must be controlled.

"In the same way your car has natural harmonics, machines have a natural frequency, or harmonics, within them," Davis said. Varying the spindle speed may lead the operator to find a "sweet spot" that is virtually vibration-free.

Careful tool selection can help avoid breakage. To maximize tool rigidity, it's best to use the largest-diameter tool that will fit the feature being machined, as well as one with the shortest flute length. The number of flutes on a tool is a factor in calculating chip load, and the more flutes the better, Liechti noted. However, when tools approach 0.005" in diameter, "you don't have a lot of choice [in terms] of flutes. You can't get four flutes in there," he said.

The features being machined also dictate other elements of tool selection, according to Liechti, who noted that some moldmaking applications require machining deep ribs. For example, with a 0.010"-dia., 2-flute tool, the operator would have to take very light cuts. Machining deep features requires a relatively long tool. The disadvantage is, the longer the tool, the less stable it is, and vibration becomes an issue. Feed and speed must be adjusted to eliminate the vibration.

Also, improper coolant application can boost cutting pressures and lead to breakage. In certain cases, the concentrate in water-based coolant should be increased to provide more lubricity, according to Harvey Tool's Davis. He added that cutting oil provides the greatest lubricity, and some shops are using vegetable-based oils that boost lubricity but are more environmentally acceptable than traditional petroleum-based fluids.

Davis described a case where a medical-parts manufacturer using water-based coolant was achieving 3 days of tool life when applying long-reach tools to cut titanium. A change from water-based coolant to a vegetable oil, with all other factors remaining the same, boosted tool life to 2 weeks.

Burton noted that with 0.006"-dia. and smaller tools, the viscosity of the coolant becomes important. "You have to have a very low viscosity for that coolant to actually flow through the flutes because they are so small." As a result, some shops have begun applying a WD-40-like solution as a low-viscosity alternative to traditional coolant when machining with microtools, he said.

Sometimes, very small tools write their own rules. One surprising phenomenon Burton reported was that in some applications, the smallest microtools (under 0.002" in diameter) can still be productive when broken. "We've found that after the tool is broken, because of the natural way it breaks, there is usually about a half-pitch to a full-pitch length of flute left. It basically becomes a 1-flute cutter. By just plunging a little deeper, the broken tool can last two or three times longer than the original tool. That's a trick we've learned from people who are not cutting very deep."

To protect a delicate microtool, toolpath programming should focus on gradual loading and unloading of cutting pressure.

In other cases, the small amount of flexibility characteristic of a microtool can help minimize the effects of runout. "You actually can get away with some runout," Burton said. If a 0.004"-dia. endmill survives a plunge cut on a machine with perhaps 0.0005" runout, feeding the tool to mill a pocket or slot creates drag that flexes the tool in the opposite direction and cancels the runout's effect. "The slot actually ends up to-size or close to-size," Burton said. µ

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