cover story

JANUARY 2003 / VOLUME 55 / NUMBER 1

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The Skinny On Microdrills

The correct application of microdrills requires attention to numerous operational parameters.

The pursuit of productivity when applying microdrills (tools less than 0.125" diameter) may be as much creative as it is scientific. The characteristics of the drill itself, machining parameters, hole depth, setup integrity and workpiece composition play delicately intertwined roles.

"In some cases, all you're doing is guessing," said Mark Megal, marketing manager, Guhring Inc., Brookfield, Wis.

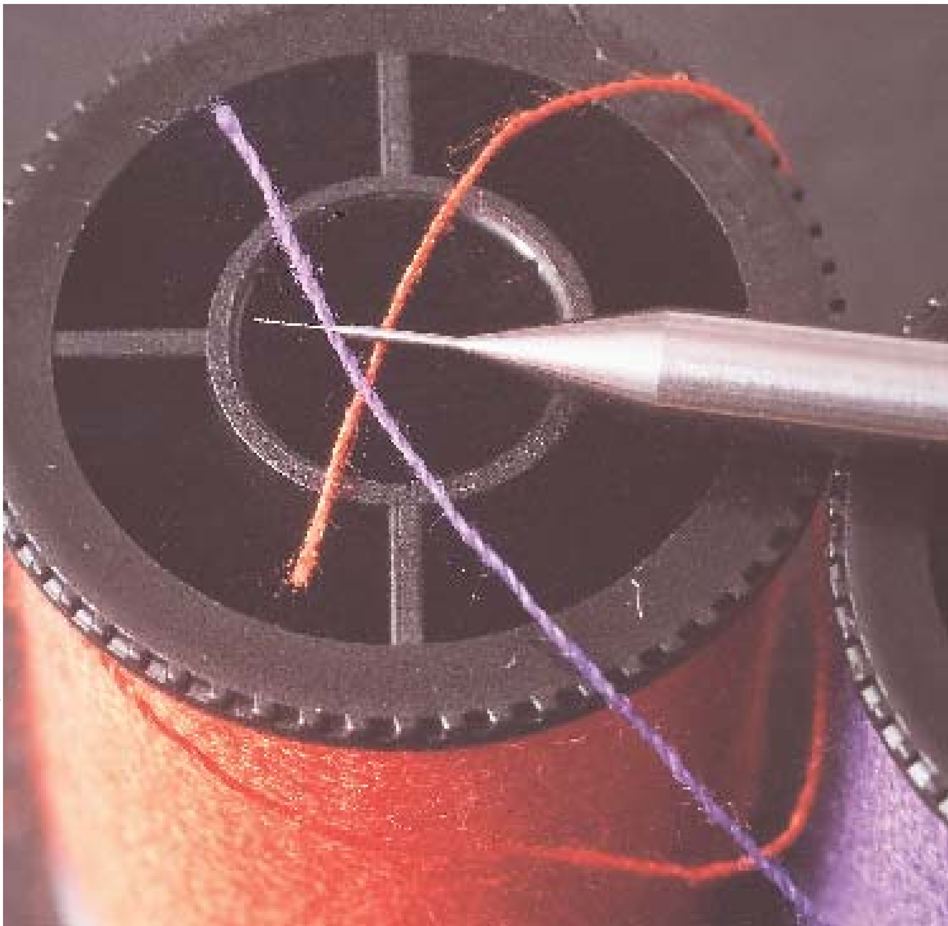
Fortunately, tool manufacturers have developed microdrill materials and geometries that take application substantially out of the realm of trial and error. Yet the task is not simple, and many factors must be considered and controlled to get the most out of these tiny tools.

Out of Proportion

As a drill gets longer, relative to its diameter, its tendency to bend increases. A low length-to-diameter ratio minimizes the deflecting forces that break drills and produce crooked or mis-sized holes. Deeper holes mean higher length-to-diameter ratios. In general, hole depths three or more times drill diameter are considered "deep." But microdrills usually far exceed those ratios.

For example, drilling a 1.25"-deep hole represents a length-to-diameter ratio of 10:1 for a 0.125" drill. Even more extreme, drilling a 1"-deep hole represents a length-to-diameter ratio of 50:1 for a 0.020"-dia. drill.

Deflection becomes more of a problem as drills grow smaller and more fragile, and the degree of fragility reflects the trade-off between the substrate's hardness and toughness.



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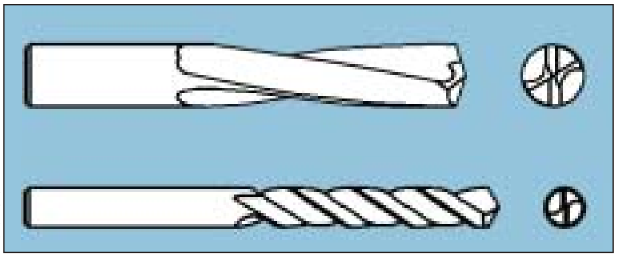
A solid-carbide, 0.0039"-dia. drill from M.A. Ford compared to common sewing thread. While carbide imparts rigidity that assists in producing accurate hole sizes and location, that same quality makes such drills more prone to fracture.

In general, HSS drills offer a level of flexibility that enables them to endure some bending forces. But their resilience—and lower hardness—is accompanied by lower wear resistance that can limit tool life.

Carbide, on the other hand, possesses high rigidity and hardness that can provide longer tool life and higher accuracy.

Joe Kueter, drilling products manager at M.A. Ford Mfg. Co., Davenport, Iowa, said carbide's high wear resistance enables users of microdrills, as a rule, to triple cutting speeds in many materials. Tool life can increase as well. "The extra rigidity of carbide helps with hole size and location, too," he said.



M.A. Ford

The slow spiral (12° helix) and thick cross section of the drill pictured at top make it better suited for drilling tough-to-machine materials than the 35° helix drill, with thinner cross section, pictured below.

Carbide isn't a panacea, however, because the extra rigidity makes it likelier to fracture.

Peter Jones, field sales engineer, Guhring, said M-35 cobalt steel is a good compromise between carbide drills and those made of M-2 and M-7 HSS. "When you generate heat in a hole, you roll the edge of the drill, and it becomes dull and plows, and the tool breaks," he said. "Higher cobalt content gives a drill higher heat resistance and it will stay sharp much longer."

Carbide drills also require careful setup and application. Accurate alignment is essential to assure that side loads will not fracture the drill.

Larry Brenner, senior milling and drilling products manager, Mitsubishi Materials USA Corp., Irvine, Calif., recommends that whenever possible, microdrills should be applied on machines where the drills rotate, such as machining centers, as opposed to applications where they are stationary, such as lathes. He noted that a machining center spindle establishes a centerline for the drill, while an off-center rotating workpiece in a lathe can cause deflection. "You have to do some alignment homework to get everything extremely straight if you work with a lathe, because carbide doesn't bend very well," Brenner said.

If microdrilling is to be performed on a lathe, it can be worthwhile to rebore the station on the turret that will hold the drill. Using an adjustable boring bar in the chuck will assure precise alignment of drill and workpiece.

Further, toolholder runout must be minimal. Said Brenner, "The number one preference is heat-shrink [toolholding]. Number two is a hydraulic chuck. We ask for 0.0002" to 0.0003" runout maximum at the collet face."

No Pilot Error

The first few revolutions of any drill are crucial. The tip of a twist drill experiences eccentric forces as it begins the cut, and any irregularities on the workpiece may cause the drill to walk, resulting in tool bending, breakage or, at least, an imprecise hole.

For drills under 3mm in diameter, Mitsubishi recommends making a starter hole 1 to 2 diameters deep using a short, stiff pilot drill.

The tip of a pilot drill for microdrilling should have an included angle that is the same or greater than that of the drill that will make the final hole. Lesser included angles can cause the cutting edge to chip, because it will contact the work before the drill point.

In lieu of a pilot drill, start the microdrill into the hole at a feed rate far below the finishing feed. Take the case of drilling a 0.5"-deep hole with a 0.0635"-dia. drill. If the tool's feed is specified at 0.002 ipr, one might start the feed at 0.0005 ipr for a depth of 0.01", or "until the drill margin is engaged," said Brenner, "to prevent it from walking."

Another challenge is spinning a microdrill fast enough to take full advantage of its productivity potential.

"In most cases, the drill is way ahead of the machine tool" in terms speed capability, Brenner said. Many machines can be run at their maximum rpm and still not achieve optimum cutting speeds for the tiny drills. For example, achieving 300 sfm with a 1mm-dia. drill requires a spindle speed over 28,000 rpm.

The hardness of the material being drilled makes a big difference in starting-point speed and feed recommendations for microdrills. For example, for a 0.052"-dia., solid-carbide drill cutting 1018 mild steel (20 HRC), M.A. Ford recommends a cutting speed of 300 sfm and a feed of 0.0015 ipr. On the other hand, the same drill can handle softer materials, such as plastics and composites, at 650 sfm and 0.0050 ipr. In harder-to-machine materials, however, such as nickel-base and titanium alloys, speeds of just 50 to 60 sfm are recommended, with a feed of 0.0012 ipr.

Pecking Order

Traditionally, deep-hole microdrilling requires "pecking"—periodically retracting the drill to break chips and avoid chip packing. Pecking also can help avoid dwell at the bottom of the hole, which is important when drilling materials that workharden.

"People think you have to come out of the hole all the way when pecking," Brenner said, "but if you interrupt the feed for a couple of revolutions or a short time, the chip will break."

Also, complete withdrawal may result in a taper at the hole mouth or may leave chips in the hole that will need to be recut—an undesirable situation.

Problems usually occur in the last 20 percent of the hole's depth.

"It's very difficult to get the chips out as you get deeper," Brenner said, "but every job is different, and it may take an application engineer to make the decision on pecking, depending on the job and material."

Although microdrills for printed circuit boards can be similar in diameter and material makeup to microdrills designed for tougher workpieces, their geometric differences can be significant.

M.A. Ford's Kueter said that circuit

board drills can work in harder materials if special attention is paid to setup, but, generally, his company fine-tunes its tools for tougher work. One approach: Shorten the flute length as much as possible to increase strength.

"If a customer is going to drill to a depth of 1", we won't necessarily give them 1" of flute length," he explained. "We'll give them ⅜" or ½"."

Some circuit board drills feature what Kueter calls a "step flex shank." An example of this feature would be a 0.006"-dia. circuit board drill, designed to drill 0.060" deep, having flutes extending the full 0.060". But instead of stepping up directly to a 0.125" shank above the flutes, the supplier steps up to an intermediate diameter of 0.030".

"For customers drilling tougher materials, we will get rid of that step, because we want as little hanging out there as possible," Kueter said.

From a geometric standpoint, circuit board drills generally feature a higher helix angle ("faster" spiral) and thinner flute cross section than other microdrills.

"When we make drills for stainless and similar tough-to-machine materials, we go with a 'slower' spiral and a thicker cross section," Kueter said.

To reduce stress on a microdrill, back taper—a decrease in diameter from the point to shank—can be critical. Typically, microtool back taper may total 0.0002" to 0.0005", because the flutes are often less than 1" in length. Ordinarily, back taper is 0.0005" to 0.001" per inch.

"Whatever depth you're going to drill, you're going to need back taper," Kueter said, "especially when drilling materials like titanium, which will shrink back as you drill them. If you don't have adequate back taper, you could bind up in the hole."

Kueter related one customer's unique approach to overcoming titanium's tendency to shrink back during machining. "He asked us to send drills at the highest end of the tolerance for point runout. He figured that the cut would be a little oversize and wouldn't shrink back as much on the drill," Kueter said.

Better Through Through-Coolant

Through-coolant drills are a proven way to boost productivity when deep-hole drilling. Not only does fluid go directly to the drill point to cool and lubricate, it also forcefully evacuates chips and helps break them. Coolant-fed drills are beneficial in holes deeper than 3 diameters. Until recently, though, through-coolant has been limited to drills 3mm in diameter and above.

Colin Eldon, national sales manager, CoolJet Systems, a Brea, Calif.-based provider of high-pressure coolant systems, said a properly applied HPC system for drilling can significantly improve productivity. He recalled how a customer was drilling a 0.055"-dia., 0.525"-deep hole in a 302 stainless steel medical part with 60-psi flood coolant. "It took 42 seconds to make the hole with a cobalt-HSS drill run at 1,600 rpm, 0.001-ipr feed and a 0.01" peck."

Drills required replacement about every 175 parts.

The manufacturer switched to two drills and high-pressure coolant. First, a noncoolant MZE solid-carbide pilot drill from Mitsubishi made a starter hole 0.10" deep, running at a 6,000-rpm spindle speed and 0.001-ipr feed. Then, a coolant-fed Mitsubishi MZS microdrill, running at 9,000 rpm, a 0.0008-ipr feed and a 0.055" peck finished the hole. Coolant pressure was 1,500 psi. Total drilling time was reduced to 16.5 seconds, including drilling the pilot hole. Tool life increased to over 875 parts. The 60 percent reduction in drilling time and the time saved due to fewer drill changes outweighed the 3.3-cent increase in drill cost per part of the advanced drills.

Mitsubishi's Brenner said for his company's coolant-fed microdrills—which range in diameter from 1mm to 3mm—coolant pressure of at least 1,000 psi is specified. The requirement is a function of the drills' two tiny coolant holes, which measure about 0.006" in diameter for the smallest drills. The pressure is necessary to produce adequate volume. A large drill, one with 0.060" coolant holes, might pass 4⅓ gpm at 1,000 psi; at the same pressure, a microdrill may pass only a half gallon.

Mitsubishi also recommends that the coolant system filter out particles as small as 5μm. If a high-precision collet is used, it must be able to seal off 1,000 psi, either with internal sealing or external seal disks and rings. A water-soluble coolant, with EP additives such as sulfur and chlorine, is recommended. Oil is not, as it is eight to 10 times more viscous than water-soluble coolant.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A solid-carbide, 0.055"-dia., through-coolant drill from Mitsubishi (left) is used to drill a 0.0525" hole in a 302 stainless steel medical component (right). Units on the ruler are 1⁄32".

M.A. Ford put a special web taper on its latest line of coolant-fed microdrills—which are as small as 1mm in diameter—to help maintain drill strength. "The coolant holes spiral through the drill and can get close to the front or back of a flute," Kueter explained.

The company is looking at a slower spiral helix for coolant-fed drills, because it can help get chips out of the hole. Kueter said the through-coolant drills should significantly cut down on the need for pecking, especially in materials like 304 or 316 stainless, which can workharden.

Tiny Holes, Big Challenges

Starro Precision Products, Elgin, Ill., which provides Swiss screw machining and other manufacturing services, has worked closely with M.A. Ford in the application of through-coolant microdrills. Lee Dwyer, Starro's vice president of sales and manufacturing, said, "You have to know what you're doing with coolant and the geometry of your tool."

Starro differentiates itself by holding tolerances to ±0.0002" in some production runs. Dwyer said that most of the available drilling data covers rotating applications, so Starro has had to develop many of its own procedures for using microdrills on screw machines and CNC machining centers. "Centering is the trick," he said. "You must have very good machines and less than 0.0001" TIR."

Dwyer said that the major benefits of the coolant-fed microdrills are increased tool life and speed. Depending on the workpiece material, through-coolant drills can provide three times the tool life and 30 percent faster cutting speeds than noncoolant-fed carbide drills.

Optimizing every element of the overall cutting system is especially important in long-run microdrill applications.

Tom Krueger, national sales manager for Kyocera Tycom Corp.'s Micro Industrial Cutting Tools division, Irvine, Calif., said lower-volume machine shops can get cost-effective performance with standard tools, but, where high volumes of a specific product are involved, a shop should analyze and optimize the entire operation.

With a special drill, point geometry, flute length, helix angle, and shank length and diameter can each be adjusted for achieving the best performance in a particular workpiece material. Analysis of the machine tool used to apply the drill can further increase output.

Krueger cited a stainless steel medical product application involving a 0.015"-dia. drill. The process was performed on a unique machine that rotated the drill at 5,000 rpm while rotating the workpiece at the same speed in the opposite direction. Kyocera Tycom suggested process modifications, such as changes in machine alignment, that doubled part output.

Realizing major gains in productivity takes time, money and commitment. Starro, for example, invested in equipment and processes and conducted extensive research on various microdrilling applications.

"It's not for the faint of heart," Dwyer said.

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