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January/February 2010 Volume 3 Issue 1

SMALL DOSE

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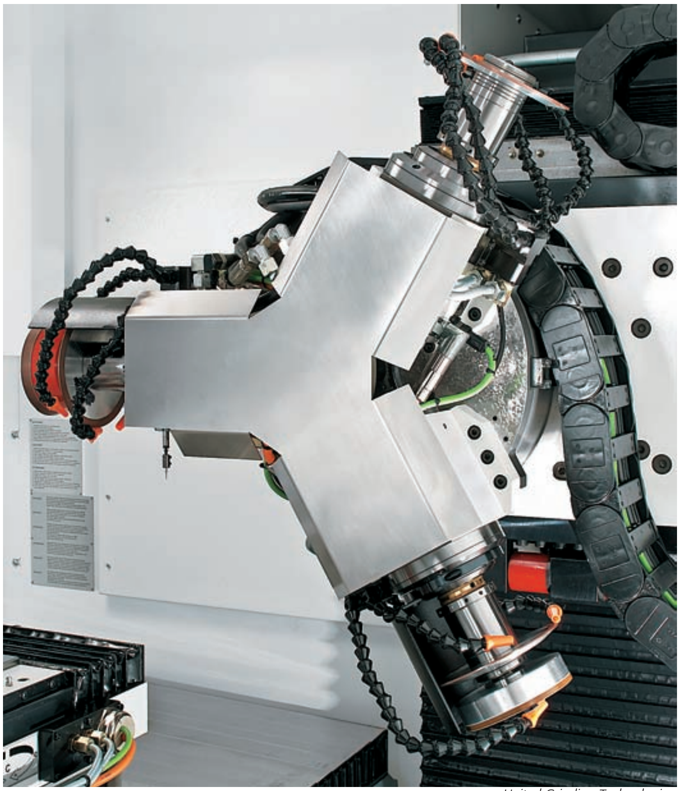
A Better Grind

Keys to productive grinding of microscale tools

By William Leventon

As cutting tools shrink, difficulties grinding them grow. Particularly as diameters slip below 0.020", manufacturers of microtools struggle to minimize runout and vibration, hold grinding points steady and avoid subjecting the delicate tools to excessive force.

How are toolmakers meeting today's microgrinding challenges? The latest machines are a big help, offering features and capabilities that improve both the grinding process itself and the tools made during the process. Other advances have impacted the wheels used for microgrinding operations, giving users more wheel choices and wheel-dressing options.



United Grinding Technologies

The Walter Helitronic microtool grinder features three direct-drive spindles on a rotary B-axis, which is itself a torque motor.

But there's more to the story than state-of-the-art equipment. Toolmakers are also applying their own special techniques to the task of meeting microgrinding challenges.

Microgrinding machines

Nothing has had a bigger or more positive impact on the process of grinding microtools than developments in machine technology. Five years ago, for example, minimizing runout when grinding "had to do with artistic touch," said Dave Burton, president of toolmaker Performance Micro Tool, Janesville, Wis. "But today, the equipment being manufactured is quite good at that."

Today's most advanced machines offer features aimed at making the tough job of microgrinding a little easier. Take linear motors, which have been used for some time on milling machines. In the last few years, manufacturers have been installing these motors in grinding machines, according to Simon Manns, tool grinding applications manager for Walter/United Grinding Technologies Inc., Miamisburg, Ohio, the North American arm of Schleifring Group, the manufacturer of Walter and other grinding machines.

Linear motors replace rotary motors, which connect to lead ballscrews that attach to machine parts to move them. Small amounts of movement can occur at the points where the ballscrew is attached to the motor and machine part, which can adversely affect grinding accuracy and the surface finish of small tools. In addition, Manns noted, a lead ballscrew wears over time, impacting a grinding machine's ability to hold tight tolerances.

These problems are eliminated by linear motors, which don't use moving parts. Instead, the motors use changes in magnetic polarity to produce machine movement, Manns explained.

Compared to rotary motors and ballscrews, linear motors also reduce cycle times by speeding up the movement of machine axes, noted David Brigham, former vice president of Schütte USA LLC, a grinding machine supplier in Jackson, Mich. Brigham added that machines with linear motors also move more smoothly than those with ballscrews, which rely on encoders or resolvers that produce incremental movements.

In many grinding machines, Manns said, a belt connects the motor to the spindle. But the latest Walter microgrinding machine includes a direct-drive system in which the wheel fits onto the end of the motor, eliminating vibration through the belt system.

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Reduced grinding machine vibration can yield a number of benefits for microtool makers, including improved surface quality and machining accuracy. Another way machine builders, such as Rollomatic Inc., are lessening vibration is by equipping grinding machines with hydrostatic slides that move on a thin cushion of oil, thereby eliminating metal-to-metal contact, according to Eric Schwarzenbach, president of Mundelein, Ill.-based Rollomatic.

Hydrostatic slides have been used for some time. In recent years, however, their cost has come down and their precision has gone up, noted Chris Morgan, chief technology officer for Advanced Machine Technologies Inc., a maker of small cutting tools in Crestwood, Ky.

Floating workhead

In addition to hydrostatic slides, Rollomatic's Nano6 microgrinding machine includes what the company calls a "floating" workhead. Normally, the workheads in such machines aren't free to make small movements. Instead, they run on ball bearings around their own axis, Schwarzenbach explained.

With a floating workhead, however, the ball bearings have been removed, leaving the workhead free to float, or move approximately 0.050". As a result, concentricity is not provided by the workhead but by the machine's shank-guidance system. "The floating workhead [yields] to the shank-guidance system," Schwarzenbach said. "So the workhead is driving but not making any contribution to accuracy."

Usually, a shank-guiding system is paired with a standard workhead. During the grinding of small tools, however, the two systems "will be fighting each other far too much," Schwarzenbach said. "With the floating workhead, we've eliminated this fighting, or stress." As a result, concentricity is improved and runout is virtually eliminated, he said.

Like hardware such as floating workheads and hydrostatic slides, software plays an important role in the latest microgrinding machines. Consider, for example, how these machines minimize movement of the grinding point, a key to accurate microgrinding. "When you get down to very small tools, if you move the grinding point a tenth (0.0001") or a couple of tenths, you're out of tolerance and you lose the tool," Manns said. Due to the importance of the grinding point location, the latest Walter microgrinding machine lets manufacturers of tiny tools design grinding processes with special software called Tool Studio, which uses all of the machine axes to try to maintain a fixed grinding point on the wheel.

Changes in wheel changing

Not surprisingly, the grinding wheel itself hasn't been ignored by those seeking to improve microgrinding processes and products. One significant change related to grinding wheels is the number of wheels that can be held by machines on the market. For example, the latest Schütte machine includes a wheel-changing device that allows it to hold up to five different wheel arbors, each of which can be loaded with three wheels. The wheel-changing device makes it easier for manufacturers to switch back and forth between several different grinding jobs, according to Brigham.

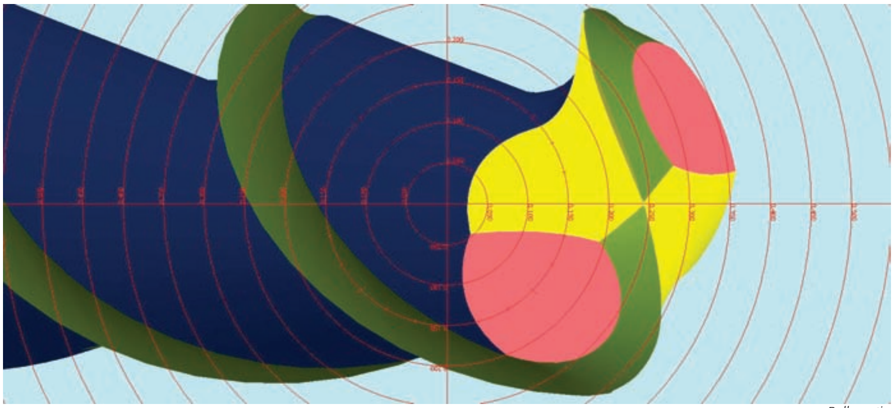
The wheel-changing device also allows manufacturers to load separate wheels for finishing, semifinishing and roughing onto the same wheel arbor. This allows them to complete all three of these processes "without ever having to stop the machine," Brigham said.

Thanks to a special feature, Schutte's wheel-changing device can come into play during finishing, when a process called "magnet finishing" is used to remove burrs. Magnet finishing is also designed to improve the coating adherence of surfaces, thereby increasing tool life. Incorporated into the wheel-changing system, a magnet-finishing unit allows grinding and magnet finishing in one setup on the same machine, Brigham noted, saving time and reducing costs.

Bond options

As for the grinding wheels themselves, toolmakers can now opt for wheels with hybrid bonds that combine metal and polyimide for better wheel-form retention. Hybrid bonds allow users to make long part runs without stopping the process to dress the grinding wheel, according to Troy Heuermann, superabrasives business manager for 3M Abrasive Systems Div., St. Paul, Minn., which makes diamond and CBN grinding wheels.

For an even harder matrix and better form retention, wheels with vitrified bonds are available. These bonds are usually vitrified diamond or CBN, depending on the tool material. Diamond, for example, would be used for carbide tools, while CBN would be the choice for tools made of steel, according to Heuermann.



Rollomatic

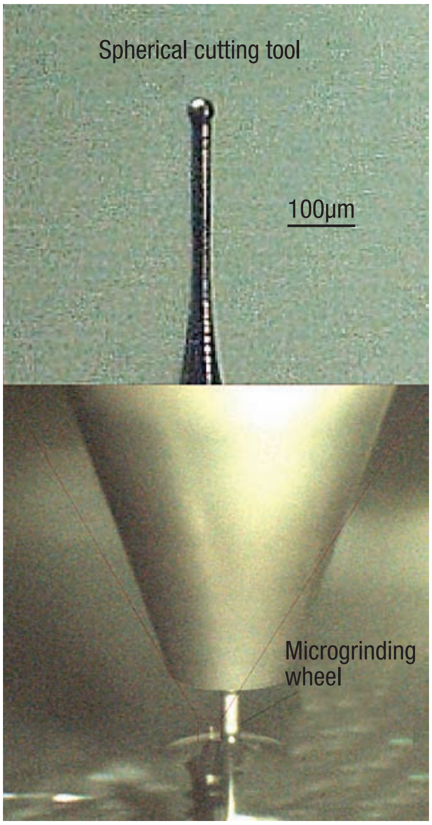
3-D simulation of a 0.004"-dia. ballnose endmill that takes into account the corner radius on the grinding wheels.

While relatively hard wheels have their advantages, softer wheels are a less-expensive option and can do an adequate job in some microgrinding applications. There are a number of different ways to make a wheel work and feel softer. One is reducing diamond concentration. Many times, Heuermann said, a softer wheel will have less diamond content, which adversely impacts form retention. But this may not pose a problem during a small production run—for example, a batch of 50 parts with a total run time of less than an hour. Even a soft wheel can sometimes provide adequate form retention for relatively short runs. If soft wheels can meet part tolerance requirements, Heuermann thinks they can be a good choice because softer bonds reduce costs, as well as the risk of burning parts during grinding.

Dressing the wheel

In addition to wheel characteristics, toolmakers must consider how to dress wheels used in microgrinding processes. Today, there's a trend toward online dressing, or dressing the wheel in the grinding machine, reported Mike Gainey, corporate applications engineer for grinding wheel manufacturer Saint-Gobain Abrasives, Greer, S.C. Online dressing eliminates runout that results when a wheel is remounted in a grinding machine after offline dressing. "The smaller the part you're grinding, the more important it is to reduce or eliminate runout," Gainey said.

To those interested in online dressing of microgrinding wheels, Gainey pointed out that the process will probably require a vitrified-bond diamond grinding wheel instead of wheels with more common resin or metal bonds. A glass-type bond, vitrified material is more fragile and will fracture more easily when dressed with a rotary diamond dresser, which is usually chosen for online dressing because it allows better measurement of wear on both the wheel and the dresser inside a machine, Gainey noted.



Advanced Machine Technology

A 200μm-dia. grinding wheel is used to fabricate a 25μm-dia. spherical cutting tool.

Users of Schütte's microgrinding machine can purchase an in-process dressing device that mounts onto the machine's workholding axis. Dressing superabrasive wheels online, however, "isn't a real quick process," Brigham said. In most cases, his customers will remove the whole wheel arbor from the grinding machine and take it to a separate dressing machine.

To minimize runout caused by offline dressing, Rollomatic offers a special wheel arbor system called PerfectArbor, which uses material deformation as a means of centering the arbor when wheel packs are remounted to the grinding spindle after dressing. This system provides greater accuracy than the tapers often used in these situations, according to Schwarzenbach.

Wheel-dressing systems of various kinds are used to create the right wheel shape to grind the required features into microtools. One option is a machine sold by 3M, which uses data from tool drawings to produce the necessary wheel profile, said Heuermann.

Performance Micro Tool, on the other hand, uses its own dressing technique to shape the profiles of commercially available wheels so they can grind microtool features. This technique "is probably the key to our success," Burton said.

Tricks of the trade

Other toolmakers devise special techniques, too. At Advanced Machine Technologies, personnel achieve greater manufacturing precision by using sensors to make sure that tool shanks are almost exactly concentric with their rotation axis on the grinding machine.

In addition, Morgan and his colleagues have their own ways of preventing small, delicate tools from breaking during microgrinding processes by minimizing tool runout. "What we do is cut at a really low speed and take our time. We'll typically operate at around 20,000 rpm, which is actually slow for grinding microtools," he said, noting that spindle speeds for grinding microtools can range from 60,000 to 200,000 rpm. Advanced also typically applies grinding wheels with diameters from 0.01" to 0.001". The combination of small grinding wheels and low speeds results in low forces on workpieces, according to Morgan.

At Performance Micro Tool, Burton handles similar situations by increasing the rotational speed of the grinding wheel without increasing the rate at which the workpiece is fed into the wheel. This reduces the amount of material removed by the individual grits on the wheel per revolution, which, in turn, reduces the force on the workpiece.

In microgrinding operations, however, there are other things to be concerned about besides the forces applied to tiny workpieces. For example, Burton points to wheel wear, vibration and the possibility of burning tools. So he and his colleagues have developed a formula that takes these factors into account in different situations and yields the optimal rate at which a workpiece should be fed into the grinding wheel. The formula "is something we've developed over the last 30 years," he said. "For the first 10 years, though, it was trial and error." μ

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