Flex Time for Grinders

By Bill Kennedy,
Contributing Editor

Multifunction grinders, which include other machining operations, enable shops to complete parts in a single setup, among other benefits.

United Grinding

In addition to holding a selection of grinding wheels, the toolchanger in this Mägerle MFP 50 grinder can carry endmills and other tools for miscellaneous traditional machining operations, enabling the processes to be consolidated on one machine.

Grinding traditionally has been performed on highly specialized machines at a deliberate pace. Now, in response to manufacturers' need to handle shrinking lot sizes and respond quickly to customer demands, grinding machine builders are expanding their machines' grinding capabilities while adding functions other than grinding.

Blending Functions

Hans Ueltschi, national sales manager for the cylindrical grinding division of United Grinding, Miamisburg, Ohio, said manufacturers in general are seeking ways to consolidate operations—be they cutting or grinding—on fewer machine tools. The primary goal is to reduce capital and labor costs. However, facing a trend to the smaller lot sizes characteristic of just-in-time manufacturing, manufacturers are also looking for flexible machines that can be quickly adapted to produce different parts or facilitate changes among a family of parts. The prevalence of outsourcing also boosts interest in machine flexibility; shops handling contracts outsourced by OEMs want machine tools they can use for other jobs after a contract is fulfilled.

According to Ueltschi, a machine that is more flexible and easier to use is actually more complex beneath the surface. "What is helping the convenience of setup and facilitating programming is software," he said. Graphically oriented, user-friendly software can guide an operator through the process and puts a simple face on complex operations.

Grinder manufacturers generally develop their own software, said Ueltschi. Third-party software like that available for turning and milling is less common because "grinding is a little bit of a niche market" compared to those more common metal-removal methods, he said.

Grinding programs are also different than those for turning or milling,

Software and hardware synergy

HI-QUALITY CARBIDE TOOLING INC., Orangeville, Ontario, performs ID grinding of carbide dies used to cold-head bolts and other fasteners. It had an opportunity to extend its range when a customer urged the shop to add the capability to grind carbide extrusion punches.

The punches range in size from 0.300"-dia. × 4"- long to 1.25"-dia. × 13"-long. The complex punches require a significant amount of contour grinding. Size tolerances are 0.0003" to 0.0005". However, Hi-Quality Carbide President Tim Middlehurst said, "It's the surface finish that is critical." Completed punches require a polished mirror finish. In preparation for polishing, chatter-free, ground finishes in the range of 2µin. R_a to 3µin. R_a are necessary. The punches were an entirely new product line requiring the addition of a CNC OD grinding capability.

Middlehurst researched CNC OD grinder technology and chose a Studer S33 CNC grinder. The machine features a center distance of 25.6", a center height of 6.9", a maximum speed of 1,500 rpm and a maximum workpiece weight of 176 lbs. Drive capacity of its external wheelhead is 10 hp. The ISO 50 universal workhead is capable of both live spindle grinding and grinding between centers.

"One thing that drew us to the Studer was the software," Middlehurst said. "We use the StuderPROFILE software of the StuderGRIND package to redraw the part offline," he said. "We have a PC out on the shop floor hooked to the machine with an Ethernet cable, and that's where we make our drawings. While the machine is running, the operator can be setting up all the contours for the next job. That information is transferred to the machine control as subroutines that are input into the Pictogramming software." Pictogramming leads an operator through steps in grinding a part and then generates G code.

Every punch profile is unique. It is notable, therefore, that Hi-Quality Carbide doesn't dress wheels to match the individual profiles. The shop uses a straight-front, flat, ½"- or ⅞"-wide wheel, applied in plunging and oscillating passes to establish the punch diameters. The same wheels grind the profiles. "The trick is that we have a rotary disc dresser that forms a radius on each wheel corner, and we use that same corner radius to profile all of our contours," said Middlehurst.

He also exploits the workhead's capability to support both live-spindle grinding and grinding between centers. He processes the punches in two steps, first grinding the main body between centers, then chucking the punch's back end and finish grinding the profiled end. Between the dead centers, a brass drive dog holds the end of the shaft and picks up a pin on the workhead to spin the part. "We grind the major diameter, chuck it, indicate off it and then do our contours on the end," Middlehurst said.

—B. Kennedy

Hi-Quality Carbide redraws part prints on a PC linked to the shop's Studer S33 CNC grinder. The arrangement enables an operator to set up the contours for the next job while another job is running.

United Grinding

because they typically direct basic plunging or transverse movement of the wheel, Ueltschi said."There are typical types of grinding cycles—you call them canned cycles—that can be picked by the operator depending on part requirements," he said. In some cases, software makes recommendations not only on wheel movement but also on feeds and speeds, based on the grinding wheel material and part specifications.

Grinding software also enables virtual setup, simulation and offline programming. "It permits running a simulation to see if your work envelope is correct, the position of the workhead and the whole toolholding area is correct, and it will show if you have interference," Ueltschi said, adding that the virtual setup data facilitates the setup of the actual machine and workpiece (see sidebar on page 52 for an example of a shop that takes advantage of software and machine flexibility).

Sophisticated software can also permit fast switching between metal-removal functions to increase productivity. Although hard turning and grinding are often pictured as an either/or choice, Ueltschi recently presented a webinar in which he discussed the benefits of combining hard turning and grinding on one machine.

He first examined the advantages and disadvantages of each process. The advantages of grinding include the ability to consistently generate extremely fine surface quality and concentricity, the absence of a screw-thread-like "lead" line as produced by a single-point cutting tool, and the relatively low cost of metal-removal tools (grinding wheels). On the other hand, grinding is somewhat limited in the complexity of contours it can produce, residual coolant and swarf pose waste management issues, and cycle times can be long when heavy stock removal is required.

In contrast, hard turning tools can easily produce complex contours, are usually run dry and remove material relatively quickly. However, turning tools generally can't impart surface finishes as fine as grinding can, compensation must be made for insert wear, and the PCBN tools typically applied in hard turning are expensive and may fail in interrupted cuts.

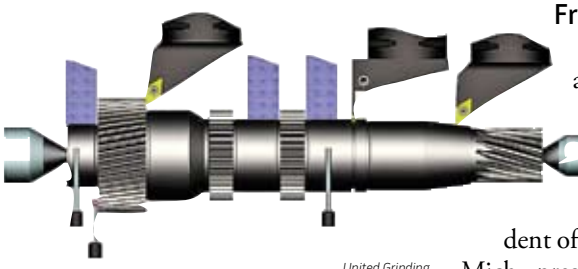
Combining the two processes on one machine leverages their strengths. Excess stock can be removed quickly via hard turning, followed by the application of a grinding wheel optimized for the particular finishing operation. Features such as grooves that are difficult to reach with a grinding wheel can be hard turned. Limiting grinding to finishing passes

keywords

AXIS:
Imaginary line passing through center of an object, around which the object can rotate.

SUPERABRASIVE TOOLS:
Abrasive tools made from diamond or CBN, the hardest materials known.

—CTE Metalworking Glossary



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To reduce workhandling and boost productivity and accuracy, grinding machines increasingly are engineered to handle additional operations. This graphic representing processing of a hardened transmission shaft on a Studer S242 grinder shows grooves, faces and contours being hard turned while critical bearing and seal areas are ground. Tolerances of ground surfaces are verified with in-process probes.

minimizes cycle time and the amount of swarf produced. Changeovers are fast when machining a family of similar parts because CNC turning operations can be reprogrammed quickly to handle changes in features and grinding wheels can be chosen to achieve specific finish requirements.

Ueltschi used the Studer S242 as an example of a machine engineered to handle grinding, hard turning and other operations. The machine has a 9.1-hp grinding spindle and is for grinding, turning and milling small to medium-size workpieces up to 1,000mm long with a maximum OD of 180mm. A workpiece can be held between centers or in a chuck. A rigid, longitudinal slide has two independently controlled cross-slides. The cross-slides can be individually equipped with an external wheelhead, an internal grinding attachment for up to three grinding spindles or a rotary tool turret for up to 10 tools, including optional driven spindles for milling and drilling.

Ueltschi described a between-centers application for the multifunction machine that involved a hardened transmission shaft on which grooves and faces were hard turned and critical bearing and seal areas were ground. In another situation, where a gear was held in a chuck, the sequence of operations included backface grinding, preturning of the bore, face turning, preturning of the OD chamfer and OD taper and final grinding of an OD taper, all in a single clamping.

Free-Form Flexibility

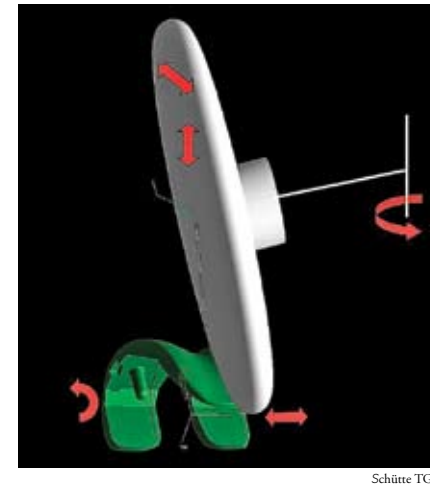
Multifunction machines are also used to process the essentially free-form parts commonly seen in the aerospace and medical industries. David Brigham, vice president of Schütte TGM LLC, Jackson, Mich., presented the company's 305 Linear universal grinder as an example of flexible part-processing technology. The machine has an X-axis travel of 15.75" and Y- and Z-axis travels of 10" each, with AC linear drives on each of its five CNC axes. According to Brigham, use of linear drives minimizes many issues that arise with ballscrews and other mechanical components, including backlash and wear. He noted that linear drives are known for generating heat during operation, but said Schütte developed cooling systems featuring proprietary components and techniques that efficiently carry heat out of the machine and the

motors, preserving the benefits of the direct linear drives.

The machine's wheel-changing device is similar to a toolchanger on a machining center, Brigham said, and it can hold cutting tools in addition to grinding wheels. "We are able to take a casting or a forging that needs to be milled, ground, belt-sanded and polished and do it all in one holding," he said. He added that the milling operations do not involve heavy material removal; "we're not milling a block of aluminum. We are taking maybe a couple hundred thousandths of stock off."

Brigham used a customer's processing of a chrome-cobalt alloy casting for a knee implant as an example of flexible processing capability. The implant was ground to near-net shape with an electroplated CBN grinding wheel. The wheel was dressed to a full radius shape, which enabled grinding of different size implants in a part family with the same wheel. To effect full 5-axis grinding, the wheel moved in three axes and the workpiece in two axes.

In addition to the CBN wheel, the machine's tool magazine held a belt-sanding unit with a contact wheel driven by an idler roller, a buffing wheel mounted on a shaft and an endmill configured to fit the machine spindle. A full 5-axis post-processor for use with Unigraphics CAD/CAM software was specially designed for the application. The NC program also controlled the supply of



Schütte TGM

This 3-D model representing grinding of a chrome-cobalt alloy knee-implant casting on a Schütte 305 Linear grinder illustrates 5-axis grinding: the wheel moves in three axes while the workpiece moves in two axes. Use of a full-radius electroplated CBN grinding wheel enables different size implants in a part family to be ground with the same wheel.

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coolant and polishing compound, which are critical when machining high-performance materials used in medical applications. The coolant system itself was designed with flexible application in mind; Schütte worked with a supplier to develop a system to handle waste generated by the different processes, including grinding sludge, milling chips, sanding-belt swarf and residual polishing compound.

Material Management

Grinding high-performance materials can require flexible application of grinding parameters as well as upgrades to elements of the grinding system. Eric Schwarzenbach, president of Rollomatic Inc., Mundelein, Ill., described a customer's grinding of a titanium implant used in orthopedic reconstruction. The surface of the 1½"×2" implant curved in two planes. Schwarzenbach said the final parts required a mirror finish, but "we can only go so far with grinding. Of course, the better our grinding finish is, the less hand polishing they have to do."

The 12µin. R_a finish required two wheels: an electroplated wheel for roughing and a copper-bond CBN wheel for finishing. They were applied on a Rollomatic GrindSmart 620XS, a 6-axis CNC grinder with X-, Y-, and Z-axis strokes of 12.5", 8.6" and 7", respectively. The machine has glass scales with accuracy to 0.000002".

Grinding the titanium, Schwarzenbach said, required multiple passes. "We didn't do creep-feed, full-depth grinding," he said. "It's too much for superabrasive wheels in this kind of application." Compared to grinding steel, the stock-removal rate is lower and rpm is higher, but the feed rate is "not too much different," Schwarzenbach said.

Minimizing heat buildup in the part is crucial, so the machine was fitted with a coolant pump that had more than twice the standard horsepower (8 hp vs. 3 hp), boosting output to 40 gpm vs. 15 gpm with the standard pump.

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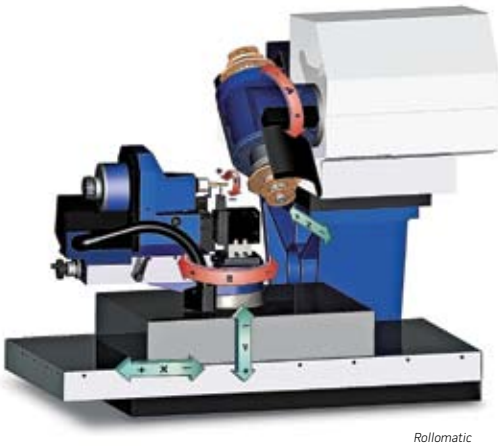
The Blohm Prokos grinder's linear motor drives provide the acceleration and accuracy required for fast, accurate processing of high-value parts, such as this nickel-base alloy turbine component.

Schwarzenbach said the shop grinding the implants devised its own workpiece fixturing system to facilitate automatic loading and untended operations.

High-Value Focus

The trend toward "multitasking, or doing more to a part while you have a hold of it, certainly has grown a lot over



Rollomatic

A Rollomatic GrindSmart 620XS CNC tool grinder, engineered to create complex tool geometries, has six axes of possible movement, so it can also be applied to grinding essentially free-form parts commonly seen in the aerospace and medical industries.

the last few years," said Chris Stine, vice president of United Grinding. "We have the capability within our equipment to use multiple spindles as well as perform multiple operations on one machine."

Stine said a key area of machine development involves the ability to change wheels quickly. "If you think of how a machining center changes tools rapidly, from a milling cutter to a different kind of milling cutter, we can do that with grinding wheels now." Such changes can involve switching to a different wheel to create another part feature or simply replacing a worn wheel.

Grinding is still the main purpose of United Grinding's multifunction grinding machine, with up to 20 percent of machine time devoted to miscellaneous machining operations, said Stine. The main reason to add machining operations is to minimize workhandling. "We have a major installation where the parts weigh 5 tons," said Stine. "Obviously, the customer has work-in-process and workhandling issues, so he wants to do everything to the part that he can in one holding. In that particular case, he turns, bores and grinds all in one machine."

Regarding markets for the advanced technology, Stine said, "A lot of the development of our equipment is focused on the turbine industry, grinding high-value parts, although I wouldn't say that's the only user of this equipment."

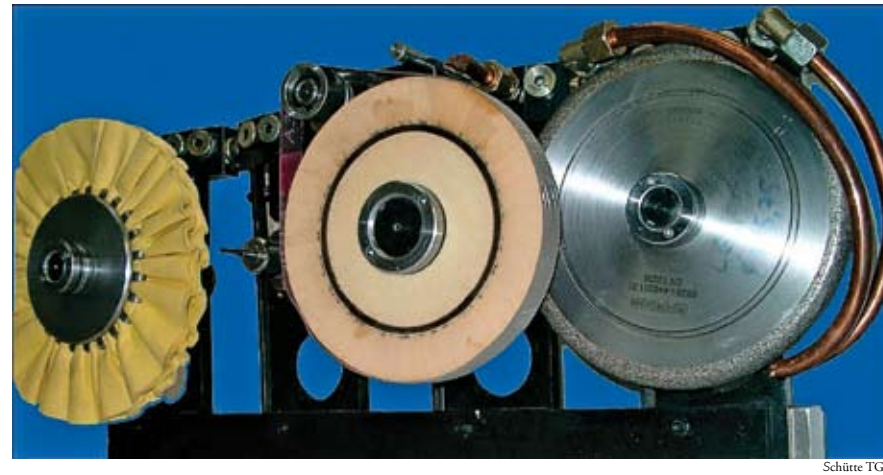
Further developments related to the processing of high-value components include part measurement and part probing within the machine. "We find that customers look more and more for the ability to verify a part is correctly fixtured," he said. "Secondly, you may do some on-machine part probing—not as a final measurement by any means—or final qualification. It is more from a standpoint that you verify over a long period of time that you have no changes in machine condition."

The development of the Blohm Profimat MC 5-axis grinder is an example of these technology trends, according to Stine. The traveling-column machine has an integrated automatic toolchanger that can switch wheels in 8 seconds using a swing arm configuration. The tool-changing system can handle up to 24 tools. The machine is focused on the aerospace market and operations with lean manufacturing practices.

Describing a typical user of the machine, Stine cited a turbine part maker that worked with Blohm Maschinenbau GmbH, Hamburg, Germany, to develop a blade-production process that included contour milling, drilling, reaming and chamfering, as well as grinding.

The operations—creep-feed, continuous-dress grinding with vitrified CBN and plated CBN wheels, and milling and drilling—employed a total of 11 wheels and cutting tools and produced a complete part in one setup.

JIT production strategies and customer demands for kitting of sets of engine parts put an emphasis on quick changeover; readying the machine for a new tooling setup consumes about 1 hour. "The capability to produce multiaxis motion and use different abrasives and grinding methods, as well as the ability to carry out miscellaneous traditional machining operations, rounds out a complete solution," Stine said. **CTE**



Schütte TGM

The wheel-changing device on a Schütte 305 Linear universal grinder is similar to a toolchanger on a machining center in that the device can hold a variety of styles of tools as well as grinding wheels. In addition to an electroplated CBN grinding wheel, this tool magazine holds, from left, a buffing wheel, an endmill and a belt-sanding unit.