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cover story

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Turning UP the Productivity

Turn/grind machines are engineered to simultaneously cut costs and boost quality.

United Grinding

In a Stratos turn/grind machine from Schaudt Mikrosa, the spindle moves between separate turning and grinding areas to isolate grinding coolant from the dry turning operation.

One way to simultaneously boost throughput and improve accuracy is to manufacture parts on machine tools that perform multiple operations, such as turning and milling, in one chucking. Such consolidation reduces workhandling and setup time. In addition, machining a part without refixturing it eliminates errors that can stack up as the part is moved from machine to machine.

Machines that both turn and grind facilitate this consolidation and also provide a way to fine-tune product quality and extend grinding wheel life. While the technology is by no means a universal solution, it can provide significant advantages in certain applications.

Demand-Driven Development

As with most manufacturing innovations, the development of turn/grind machines has been spurred by end user demand.

Jochen Arnold, president of machine tool builder EMAG LLC, Farmington Hills, Mich., said the equipment "is not something as a machine tool builder that you dream up yourself. It's been completely driven by the market. There was a request made by one of the bigger automotive companies in Germany, and the outcome was a new machine."

The automaker was looking for ways to reduce the cost of finishing hardened parts. Previously, it would rough-turn an unhardened gear wheel or shaft on a lathe, heat-treat the part and finish it on a grinder. The multiple steps in the process required excessive workhandling time and effort, in addition to the expense of the time-consuming grinding operations.

The introduction of advanced cutting tool materials and rigid, powerful lathes gave shops the ability to turn hardened parts to final size and eliminate grinding altogether. And for many parts with modest accuracy requirements, hard turning to finish is a cost-saving alternative to grinding. But it is not a universal solution.

John Wilder, national sales manager for machine builder Index Corp., Noblesville, Ind., said, "Typically, we find there will be dimensions that you cannot hard-turn. They are just too tight. And if you have an odd geometry, you may have to grind anyway."

In addition, some parts require different levels of finish in different areas. On a particular shaft, for example, hard turning may meet tolerances for all but the bearing surfaces, which then must be ground to a finer finish.

Gunter Reihle, sales manager for machine builder Erwin Junker Maschinenfabrik, Nordrach, Germany, parent company of Erwin Junker Machinery Inc., Dayton, Ohio, said that although many applications are suited for hard turning, there are some parts that will always be ground. He described the case of a truck-axle maker that switched all of its grinding operations for a certain axle to hard turning. When some axles began to fall short of the manufacturer's 1-million-km axle-life warranty period, key steps in the manufacturing process were switched back to grinding. "Combining the two processes," Reihle said, "can be the best solution."

Turn/Grind Technologies

Multitasking is well-accepted technology, so combining turning and grinding on one machine is not a great conceptual leap. Further, machine tools and CNCs have evolved to the point that they essentially differ little in

Machines at work

Index

With an inverted vertical turn/grind machine from Index, the main spindle's range of movement in the X and Z axes allows the spindle to move over a pallet, pick up a part and bring it into the machine's work envelope, making manual or robotic workhandling unnecessary.

The machine tool builders contacted for this article provided selected specifications and typical application examples for their turn/grind equipment:

■ At a toolholder manufacturer, a Vertical Line V300 turn/grind center from Index Corp. replaced four individual setups in the machining of HSK 63 toolholders. Since being installed, centering, external grinding, hard turning and bore grinding are performed in one setup on a single machine. The benefits include shorter throughput times and less floor space devoted to separate turning and grinding machines. The biggest advantage, though, has been more consistent part quality due to constant temperature conditions and elimination of multiple chuckings. Index said surface finish reaches 2µm R_z, roundness of less than 1µm and form tolerance of less than 1µm, with no chatter marks. Cost-per-part reductions are estimated at 10 to 15 percent. The machine's X-axis and Z-axis travels are 59" and 13.3", respectively, enabling it to pick up and carry blanks to the work area. It is fitted with a counter spindle, an OD grinding spindle with a 400mm grinding wheel and an ID grinding spindle, as well as internal and external gaging systems. An interesting feature is a movable cylinder that covers the chuck on the machine's counter spindle during main-spindle operations to protect it from chips and grinding swarf.

■ Erwin Junker's horizontal-style Hardpoint 300 is used to machine a sintered automotive component that originally was manually loaded and unloaded on three different machines. Operations include turning, grinding and drilling. The part is transferred between two workheads within the machine, enabling work to be done on both ends of the part. Squareness for a crucial mating surface is ±0.010mm, and surface finish is less than 0.41µm R_a. The machine features a turning spindle with an 8,000-rpm maximum speed, and a grinding spindle with a 1,000-rpm capacity.

■ EMAG LLC described the machining of a steel variable-speed automatic transmission pulley hardened to 58 to 62 HRC. Turning operations include roughing two bores and a control surface, and finishing an end face. The control surface is finish ground with a CBN wheel through single-point peel-grinding, and the two bores are finish-ground with corundum. All operations are accomplished in a single setup. The EMAG Reinecker VSC 400DS used has a Y-axis, as well as a B-axis for turning tools, and four grinding spindles. The X travel is 33.5" and Z travel is 12.4". The main spindle has a maximum speed of 4,000 rpm and maximum power of 10kW in the grinding spindle.

■ United Grinding/Schaudt Mikrosa provided an example of a 152mm-dia. synchronizer gear wheel made of hardened (54 to 56 HRC) steel machined on a Stratos machine. Turning of front and rear faces of the wheel provides a 0.63µm R_a finish, which meets part specifications. The bore and cone of the part, however, are first preturned to leave 0.3mm of grinding stock, then ground to achieve final specifications of 0.2µm R_a and roundness tolerance of 2µm. Cycle time was reduced from 74 to 60 seconds, a savings of more than 18 percent over the previous grinding-only process. The turret of the machine permits use of redundant tools and, thus, enables the machine to run longer between tool changes. It also can be fitted with live tooling for milling and drilling operations. The grinding wheel dressing unit is fitted immediately next to the spindle head, and continual dressing enhances final part finish.–*B. Kennnedy*

EMAG

Turn/grind processing of a hardened variable-speed pulley, hardened to 58 to 62 HRC, on an EMAG Reinecker VSC 250DS includes hard preturning the pulley surface with a CBN-tipped insert (left), peel grinding the surface with a CBN wheel (center), and finish grinding two internal bore diameters with sintered corundum (right).

terms of accuracy, whether they are turning, grinding or machining centers. Generally, however, a lathe is engineered with more power and rigidity than a grinder, while a grinder favors accuracy over power.

Klaus Voos, vice president of marketing for Index, said turn/grind machines require a few specific features. “It’s a matter of adding the particular technology that you need for grinding, which you normally don’t have on a turning machine.” For example, because grinding wheels must be dressed frequently to maintain sharpness, a turn/grind machine needs provisions to dress the wheel at periodic intervals. Maintaining grinding precision may also require on-machine measuring capability that lathes don’t usually possess.

Handling the two processes’ byproducts differs as well. Unlike the chips produced when turning, the grinding swarf can cling to machine tool ways, penetrate open joints and cause excessive wear. “Turning machines typically are not that well-protected, not as much as is needed. That’s an important point,” Voos said. As a result, turn/grind machines feature increased shielding for ways and other moving parts.

The Stratos series of grinding machines from Schaudt Mikrosa BWF, Stuttgart, Germany, takes a further step: After turning, the part is transferred to a second area that is enclosed by a sliding door to isolate grinding coolant from the dry turning operation.

To achieve and maintain levels of accuracy expected from ground parts, turn/grind machines employ high-precision componentry to move the spindle and part. Arnold said the spindles on EMAG turn/grind machines are guided by hydrostatic guides, driven by a ballscrew and controlled by Heidenhain glass scales. The hydrostatic guides, he said, not only enhance part accuracy but also absorb vibration. Therefore, they can actually help improve turning tool life significantly compared to traditional guide ways. “The same thing applies to grinding,” he said. “The best you can do for grinding tools is to have a very solid dampening system.”

United Grinding Technologies Inc., Miamisburg, Ohio, the North American supplier of Schaudt Mikrosa and other grinding machines, says the turn/grind machine concept must be based on the demands of the technology with the highest accuracy, i.e., grinding. Key machine features include rigid design, temperature stabilization of all components, high-accuracy drive components, such as linear motors and hydrostatic guide ways, and built-in sensor systems.

Machine Makeup

There is no standard configuration for turn/grind equipment. Machines in the Hardpoint 300 series from Erwin Junker, for example, are built like horizontal lathes, with up to four main spindles and a maximum of six working axes. One version of the machine enables four parts to be machined simultaneously and transferred between main spindles so both ends can be machined.

A number of builders have found the “inverted” vertical turning machine approach to be an effective basis for turn/grind equipment. In this configuration, the lathe spindle hangs vertically from the top of the machine. Guided by CNC, the spindle moves on guide ways above a fixed tool table. Tools and spindles are mounted to the table in a gang-tool arrangement. The tooling setup provides enough space to mount a variety of relatively large and specialized machining units. Voos said, “We can put in high-frequency milling spindles, induction hardening, laser hardening, welding and, of course, grinding machinery.”

In addition to facilitating the mounting of grinding spindles, Voos said, another advantage of the inverted vertical layout results from the main spindle’s large range of movement in the X and Z axes. The long reach allows the spindle to be used as a part loader. It can move over a pallet, pick up a part and bring it into the machine’s work envelope, making manual or robotic workhandling unnecessary. Consequently, Voos said, a vertical machine is easier to automate than a conventional grinder. Fully automating a grinder, which has a large spindle that holds the part, can be costly. Index’s Wilder said that the capital cost of a piece of turning equipment can be as much as 30 to 40 percent less than that of a fully automated grinder.

Complementary Capabilities

Combining turning and grinding on one machine offers advantages that exceed simple process consolidation. Use of turn/grind technology can result in

Not always hard

The majority of applications for turn/grind machines involve hardened parts. But the equipment's capabilities allow users to come up with innovative solutions to out-of-the-ordinary machining challenges involving unhardened materials.

John Wilder, national sales manager for Index Corp., described one such situation as "absolutely perfect" for a turn/grind center. The part was a composite of steel and phenolic plastic. When the plastic was turned to shape, it tended to chip away, he said. The solution was to rough-turn the parts and leave 0.005" allowance for grinding. "You grab the bar one time, turn it and then grind whatever chips away," he said.

Jochen Arnold, president of EMAG LLC, said he does occasionally see special cases where "soft" parts are machined on turn/grind centers. He cited as an example a part fitted with a rubber seal. The seal could be compromised by the feed line made during turning. With a turn/grind machine, he said, "you could touch up the feed line with grinding."

An unhardened part might also be ground if it incorporates features that a turning tool couldn't produce. "Like a small snap ring surface, where the bottom radius is called out for almost no radius," Arnold said, "so you won't find a turning tool that allows you to go in that kind of sharp corner."*–B. Kennedy*

shortened grinding cycles. The reason is a difference in the amount of grinding allowance required. In the traditional turn/harden/grind process, the high temperatures applied in hardening usually produces some part distortion, which increases the amount of excess material that must be left for grinding.

Rechucking also boosts grinding allowance requirements. EMAG's Arnold said, "If you have a part that is swiveling around your centerline because you rechucked it, you need to clean it up all the way around. Even using an accurate diaphragm chuck, a range of tolerance is involved. To make up for those tolerances, you need to add more stock."

More stock (a greater grinding allowance) means a longer grinding cycle to remove the excess material. For a part that is turned, hardened and ground, grinding allowance might be in the area of 50µm (0.002"). If processing the part on a turn/grind machine eliminates the need for rechucking, that allowance can be as small as 3µm to 5µm (0.00015" to 0.00020"). Voos said, "You can turn it very close to the finish dimensions with this process, and hard turning would normally be about three times faster than grinding. So that is where you really save time."

Moreover, minute stock allowances may result in grinding passes so light that they can be completed without coolant. EMAG calls it "grind finishing." As an example, Arnold said: "Take the feed line of your turning operation. If your surface requirement spells out that there are no feed lines allowed, you grind off the feed line. Nothing more than a couple of microns, and you can grind dry. In addition, you don't have to dress your grinding wheel as often. So the dressing cycle is also better than on a regular grinder."

Turn, Grind or Turn/Grind?

Deciding if a turn/grind machine is a good investment is largely dependent on the accuracy required and production levels expected for a part. In a paper entitled "Modern Combined Hard Machining Processes," EMAG engineers Jürgen Walz and Volker Clauss wrote: "In the hard machining sector, comparisons are often made between outmoded grinding methods and modern turning processes, [which] show enormous cost savings [with turning]. However, a comparison between modern grinding techniques and modern turning methods leads to the conclusion that each process has its own advantages, and that the proper combination can lead to cost-effective solutions and achieve the desired finishing accuracy and component quality."

Grinding produces the highest levels of quality, but long cycle times are required if removal of a lot of stock is necessary. Creating complex contours by grinding can require multiple wheels and/or spindles. And control and disposal of grinding swarf is expensive. On the other hand, hard turning can be performed at high metal-removal rates, allow the cutting of complex contours and produce easy-to-handle chips, but it cannot produce the ultimate quality supplied by grinding, nor handle interrupted cuts as easily.

United Grinding provides some general guidelines regarding hard turning: When the surface finish required is greater than 4µm R_Z, cylindricity tolerance is greater than 5µm and there is no requirement for a no-lead finish, hard turning alone is probably the most efficient way to produce the part.

Beyond those recommendations, part configuration will play a role. If a shaft is long and flexible, or a bore is deep, heavy cuts might affect surface finish and make more than one turning pass necessary to finish the part. Walz and Clauss note, "A comparison between hard turning and CBN grinding shows that the latter is 10 to 30 percent faster when two passes have to be made. However, where the desired result can be achieved with a single cut, the hard turning process offers a cycle time advantage."

The specialized nature of turn/grind machines makes production levels a factor in deciding whether to invest in the technology. A turn/grind machine can't do it all, said Voss. "Our human desire to have something that does everything just doesn't work." △

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