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Safeguarding SPINDLES

By Joseph L. Hazelton,
Senior Editor

Colonial Tool

Parts manufacturers must guard their spindles from misuse and damage to keep chips flying.

Efficient, accurate production of parts means manufacturers have to minimize unwanted surprises.

They can't allow production delays, out-of-spec parts or rework because the wrong fixture was purchased for an application, a cutting tool was broken due to misuse or a workpiece was damaged by too much heat during machining.

Machine shops may think first about avoiding such surprises with their tooling, but they also must consider their spindles—the components that actually rotate their cutting and grinding tools.

For efficient, accurate production, parts manufacturers need to ensure that they obtain the right spindles and properly apply them, prevent spindles from being exposed to too much heat, and make certain they don't collide with workpieces, fixtures and other equipment. Moreover, they must protect their spindles against

Learn more about spindles

Read more commentary on spindles by visiting Joseph L. Hazelton's Web log in the CTE Community section online at www.ctemag.com. The redesigned Web site, CTE Plus, features a range of Interactive Reports, a virtual product showcase, daily industry news and editors' blogs at CTE Community.

coolant and metal dust, against their penetrating spindle housings and wrecking the internal mechanisms.

Know Your Spindles

Protecting a spindle from damage means knowing how to use it. Parts manufacturers should know their spindles' specifications so they know if the mechanisms have the power, speed and other requirements for a specific application.

They should also know the specifications of spindles they're thinking about purchasing, even when a spindle is included in or recommended for a new machine tool offered by a machine tool builder. Like parts manufacturers, machine tool builders don't necessarily know everything about spindles, so assuming they do can lead to problems.

> *Parts manufacturers purchasing a new machine tool and spindle from a machine tool builder must remember: Like them, builders don't necessarily know everything about spindles, so assuming that they do can lead to problems.*

For example, a parts manufacturer may be negotiating with a machine tool builder to buy a new piece of equipment that meets its manufacturing needs. The manufacturer knows from the builder that the machine tool has a spindle with an HSK 80-B taper. If the company isn't familiar with that spindle, it might not think twice about it and assume the spindle is a standard product that accepts standard tooling. Assuming that about an HSK 80-B spindle would be a mistake.

"It's one of the most uncommon forms made," said Daniel Springhorn, president of Diebold Goldring Tooling U.S.A., Sharon, Wis., which specializes in making spindles with HSK tapers. "Everything will be custom-made for it."

A parts manufacturer may avoid such a surprise by doing a detailed study of spindles to make certain it obtains a suitable spindle for its machine tool. However, the machine shop may not have time for such a study, so its best chance of ensuring an effective, long-lasting spindle is for it to work with the machine tool builder and spindle maker. "It's a coordinated effort between the three," said Paul Thrasher, president of Colonial Tool Group Inc., Taylor, Mich., a spindle manufacturer.

Another solution may be for parts manufacturers to purchase their machine tools from one builder. International Carbide Corp. U.S.A., a Yelm, Wash., toolmaker, uses this approach, which can indirectly protect it from spindle surprises by taking advantage of machine tool builders' engineering tendencies.

Bruce Mackey, ICC's president, said a builder tends to follow the same engineering philosophy from one generation of machine tool to the next, so the basic concept is steady even though a new generation of machine tools will be beefier or have other variations. "They usually don't make huge changes."

Even knowing spindles' specifications, a parts manufacturer may choose to misuse a spindle and thereby risk damaging it. A parts manufacturer with a machine tool built for a CAT 50 spindle may use an HSK spindle for its greater stiffness.

A machine shop may also misapply its spindles in an effort to increase its productivity. Examples include pushing a spindle to its limits and beyond and not changing a spindle from application to application to save time and thereby using the spindle in applications for which it wasn't designed.

This misapplication can lead to various damaging effects, such as overloading of the spindle.

Growth From Heat

Spindles can expand due to heat during machining, not just workpieces. According to Thrasher, a spindle can expand linearly during high-speed machining and machining that requires high horsepower for extended periods and may do so without the parts manufacturer being aware of it. The spindle's expansion, if sufficient, would move it outside of its true position, changing the tool offset and possibly resulting in out-of-tolerance parts.

Another possible consequence of expansion is the spindle's timing wheel could move outside the range of the machine tool's sensors. In that case, the machine tool won't know the exact location of the spindle and tool for a tool change.

Consequently, a parts manufacturer may face one of several possible problems. For example, the machine tool may shut down—a bad situation at any time, but worst during unattended production. Another possible problem is a loss of coordination between equipment assemblies, such as the tool and automatic toolchanger. The ATC works in unison with the spindle's automatic drawbar. If their timing is disturbed, the tool and ATC may crash into each other, which could damage both, as well as the spindle.

A machine shop can control spindle expansion through various methods. Thrasher said one method reduces heat in the spindle's bearings and motors via cooling jackets. The cooling agent is a water/glycol mixture that's maintained at a steady temperature via a chiller/heater and passed through a spindle's housing.

Another method was described by Jeff Gerlach, business developer in the Elk Grove Village, Ill., office of spindle maker Weiss GmbH. When a tool's linear position is critical to an application, a spindle can be designed so its front bearing is locked in place and its rear bearing is sur-

contributors

Architectural Glazing Technologies
(800) 345-7899
www.agtglazing.com

Colonial Tool Group Inc.
(866) 611-5119
www.colonialtool.com

Diebold Goldring Tooling U.S.A.
(262) 736-2204
www.hsk.com

International Carbide Corp. U.S.A.
(800) 422-8665
www.icctool.com

Weiss GmbH
(847) 952-4266
www.weissgmbh.de

William Sopko & Sons Co. Inc.
(888) 967-6756

rounded by a moving ball cage, allowing the spindle's shaft to expand to the rear and therefore not affect the tool's position.

A spindle could also inaccurately machine parts if it's out of position because a machinist bumped it without realizing he'd done so. "They're very sensitive components," Thrasher said.

Keeping Coolant Out

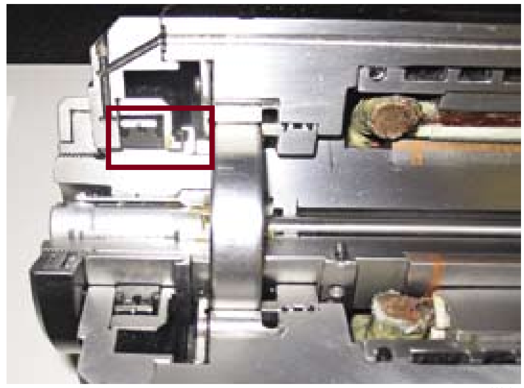
A spindle may also be damaged by coolant that penetrates its housing and reaches its bearings. "That's one of the biggest causes of spindle failure," said Tony Landl, chief engineer for William Sopko & Sons Co. Inc., Cleveland.

Besides repair work, the spindle service company also upgrades spindles that need better protection against two main causes of coolant penetration: multiple coolant nozzles and high-pressure coolant systems. According to Landl, a high-pressure system can deliver its coolant through the tool or spindle or via nozzles.

End users may be able to avoid the coolant penetration by positioning high-pressure or multiple nozzles toward the tool tip and workpiece so as little of the coolant as possible hits the spindle.

Even when delivered correctly, though, some coolant will hit the spindle, whether directly or by splashing off the tool and workpiece. Consequently, machine shops may need to use extra baffles, mechanical seals or labyrinth seals. Seals wear with time and use, though, and additional baffles can make it difficult for an ATC to reach a tool to remove it.

Another way to protect against coolant penetration is an air-purge system. Gerlach said the system is often used in direct-drive spindles to isolate the internal motor from chance exposure to coolant.



Weiss

To protect against coolant penetration, this spindle includes an air-purge system, the port for which can be seen as tubes running along the spindle's top and then down into its labyrinth seal, which is inside the red box.

He said there were two other instances in which an air-purge system should be used, instances that would apply to nearly all machining operations: when a cutting tool is accelerating and decelerating during machining and when a tool is being removed or put in place. Gerlach added that when a spindle decelerates, the air currents generated by the tool and the spindle's heat tend to draw coolant mist into the spindle and that during a tool change, an air blast cleans the spindle's taper to remove contamination before the

ATC places a tool.

Also, Gerlach said air-purge systems are less common in grinding spindles, which often involve continuous operation at high speeds, such as 100,000 rpm.

There's no rule of thumb, however, about whether an air-purge system should be used in all instances of a particular machining process, such as drilling. "Depending on the application, you may need an air-purge, you may not," Gerlach said.

A parts manufacturer may want to err on the side of caution, though, and purchase spindles with air-purge systems no matter the application. According to Gerlach, the cost of having an air-purge system in each spindle is cheaper than the cost of repairing a spindle due to contamination. However, Landl said an air-purge system would work best if it were part of the spindle's original design, that it isn't always as effective when it's retrofitted to a spindle.

Also, according to Landl, air-purge systems have become more popular recently as coolant speed—and therefore coolant penetration—has increased.

A Barrier Against Dust

An air-purge system solves more problems than just coolant penetration during machining. ICC found the system also protects spindles when they're turned off.

The company makes special rotary, tungsten-carbide cutting tools for machining fiber-reinforced plastic. The tools contain 6 percent cobalt and have a hardness of 92-plus HRA. To finish them, ICC pushes its grinding spindles to their upper limits, according to Mackey. Specifically, the toolmaker uses diamond grinding wheels and applies them at a cutting speed of 10 ipm via creep-feed grinding, forcing the spindles beyond their normal cutting rates. The toolmaker deals with the resulting heat by applying coolant at a minimum pressure of 73 psi.

ICC prefers creep-feed grinding to conventional grinding because the former reduces the number of passes to finish a tool, allowing the toolmaker to grind three times as many tools per hour.

However, ICC's grinding spindles were lasting 6 to 7 months. The problem wasn't coolant penetration, though. The toolmaker found the spindle bearings were contaminated with carbide dust. According to Mackey, even a small amount of carbide dust on a bearing will cause lapping, galling and finally spindle failure. "Any kind of foreign material would cause havoc," he added.

During grinding, the spindles were operating well, including their slingers, which divert coolant from the spindle's end. Afterward, the spindles would be turned off and their components would cool and shrink. At that point, air and carbide dust would be sucked through the slinger, into the housing and in contact with a spindle's class A bearing. The consequence for the bearing was predictable and bad.

ICC solved the problem by purchasing an air-purge system, which blows about 5 psi of air through a line in the spindle, a line that exits into the slinger. This positive internal air pressure minimized the amount of contaminated air reaching the spindle bearing as it cooled and increased spindle life to 2.5 to 3 years.

"It's very effective," Mackey said.

Avoiding Collisions

According to Bill Sopko Sr., president and owner of Sopko & Sons, collisions are happening more often and are starting to approach the frequency of coolant penetration.

Collisions are caused by a variety of problems. For example, a machinist may enter the wrong data. "You're hitting a button and forgetting a decimal point," Sopko said.

In that case, the collision can occur even if the machinist realizes his mistake right after pushing the start button. A CNC machine tool's servodrives are so responsive and fast that they can move a spindle and tool enough that they collide with a workpiece, fixture or the machine tool itself—even right after a machinist pushes the start button.

Architectural Glazing Technologies, Waterboro, Maine, avoids spindle damage from collisions by running all of its part programs through verification and simulation software.

AGT designs and manufactures structural glass products, such as monumental skylights and curtain walls. A monumental skylight can be quite large, such as 100' wide × 75' high, for example. A curtain wall is a building facade that consists of large glass panes with an aluminum support structure.

AGT purchased its simulation software, Vericut, because its CNC programming software can't provide a satisfactory representation of the machine tool for simulating a part program. "The graphical interface is lacking," said Bill Wright, AGT's production technologies manager.

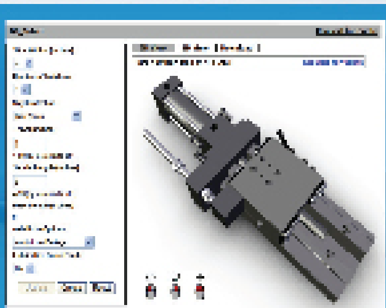
A satisfactory representation is important because AGT performs 5-axis machining.

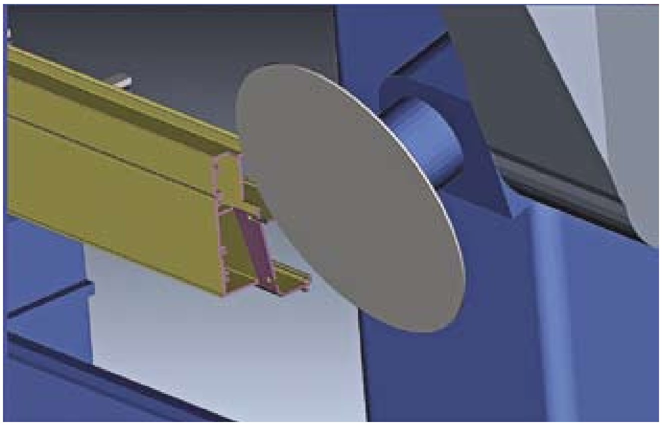
AGT mainly machines extruded aluminum, but it sometimes machines steel to reinforce its aluminum parts. It drills and slots workpieces, but much of its machining is sawing to notch parts and cut them to length. Also, a notch can be complicated, especially if it has to form a compound angle, an angle formed by two mitered angles.

Creating a complex notch can require sawing via four or more separate blade movements. Creating a notch that forms a compound angle means moving the workpiece while cutting it. That's 5-axis machining, and AGT has two profile milling centers for that work.

However, the company's CNC programming software kept it from being sure that the manufacturing components, including the spindle, would be safe from collisions before sending a part program to the shop floor. "We had to rely on the operators," Wright said, adding that "things are moving so fast they can get into trouble pretty quick."

Also, AGT generates a large number of part programs and automating simulations of them would allow it run a simulation of every program. The parts manufacturer often performs low-volume part runs and therefore creates a lot of part programs. Moreover, though AGT's parts may look similar, they can include many



AGT

Machine tool simulations can be valuable in preventing the spindle from colliding with fixtures and workpieces.

slight differences, such as various cutting angles for notches and different hole locations and angles.

AGT's high-volume jobs can also require many part programs. For example, AGT made parts for a curtain wall for a company's New York headquarters. The job required production of about 4,400 parts. "I would guess about 90 percent of the parts produced were individually unique," Wright said.

A simulation of all programs would ensure the safety of the machining process, though. Consequently, AGT purchased its Vericut simulation program in 2003. The software allows CNC programmers to prevent crashes by seeing them in simulations and changing their part programs.

While collisions must be avoided, parts manufacturers often have to bring a spindle and tool close—quite close—to a fixture or other manufacturing component to machine a workpiece accurately. AGT commonly has to bring a spindle and tool close to a vise while milling and drilling to avoid flexing the workpiece's extruded material, which could create an out-of-tolerance feature. "You want to hold the vise as close to the operation as possible," Wright said.

Also, the vise's closeness increases the workpiece's rigidity at the machining site, thereby reducing the chance of having chatter. "That's going to save you wear and tear on the spindle," Wright added.

But, closeness in a simulation can be a crash in reality because an actual machine tool can vary in the precision of its movements. AGT has a way to protect against that possibility.

Part programs are created off the shop floor, and CNC programmers check them to ensure the accuracy and safety of the machining process. This review allows programmers to see the times when a spindle and tool will be close to a vise, workpiece or both. They can then advise the machinists about those times in the machining process. Knowing their equipment, the machinists may decide that those times require them to further ensure the machine tool's movements are precise, with neither undershooting nor overshooting. "They can be prepared if they want to slow it down," Wright said.

More Complex Spindles

Also, spindle makers and part manufacturers face a future in which 5- and 6-axis machining will become more widespread and protecting spindles will become more complicated.

According to Springhorn, the trend toward more 5- and 6-axis machining means spindles will need to move in several directions to create more complex shapes, so they'll need more joints, for example, to permit movement in several axes. More joints means more points of access for coolant and machining dust.

But, first things first, protecting spindles that machine shops already have ensures the mechanisms have reasonable life spans and contribute to accurate machining of parts. **CTE**

About the Author: *Joseph L. Hazelton is senior editor of Cutting Tool Engineering. He has 7 years of experience as a reporter and editor for metalworking publications. Contact him at (847) 714-0177 or via e-mail at jhazelton@jwr.com.*