Kicking Out Bad Vibration

By Joseph L. Hazelton,
Senior Editor

High-speed endmilling of aluminum risks vibration that can damage or ruin a workpiece. But tool features and cutting strategies can be used to reach great speeds while keeping vibration at bay.

Parts manufacturers may differ in what they think constitutes high-speed machining—10,000 rpm, 20,000 rpm, 30,000 rpm or more—but they would agree that it should be done without vibration.

They'd also agree that many factors contribute to vibration-free HSM and that those factors—like tool material and design, cutting strategies and toolholder—differ in their specifics for each type of HSM and each type of workpiece material, such as for high-speed endmilling of aluminum workpieces. Consequently, machine shops should know those specifics.

Material and Design

What to look for in a high-speed endmill starts with the tool's substrate material. Tom Delleman, U.S. regional manager–Midwest and Northeast for Toolmex Corp. Inc., Natick, Mass., recommended submicron-grain cemented carbide to reduce chipping and breakage. "That's going to help you," he said. "A true submicron-grain endmill will give you a transverse rupture strength nearing that of high-speed steel."

"Equally as important as the material is the endmill's design and grind features that aid in chip control and evacuation during high-speed milling of aluminum workpieces," Delleman said. For example, polished flutes allow chips to flow more freely off the tool.

Delleman cited two other desirable features. An endmill should have a gash rollout, which permits slotting without packing and recutting chips. Also, the flutes' helix should help stabilize the endmill when it's cutting an internal or external corner. Delleman said such a helix is part of the design of Toolmex's Mako solid-carbide endmill for HSM of nonferrous metals, including aluminum. Specifically, the flutes' helix angle changes on the way up the tool, giving the endmill a variable geometry for milling a corner, for example.

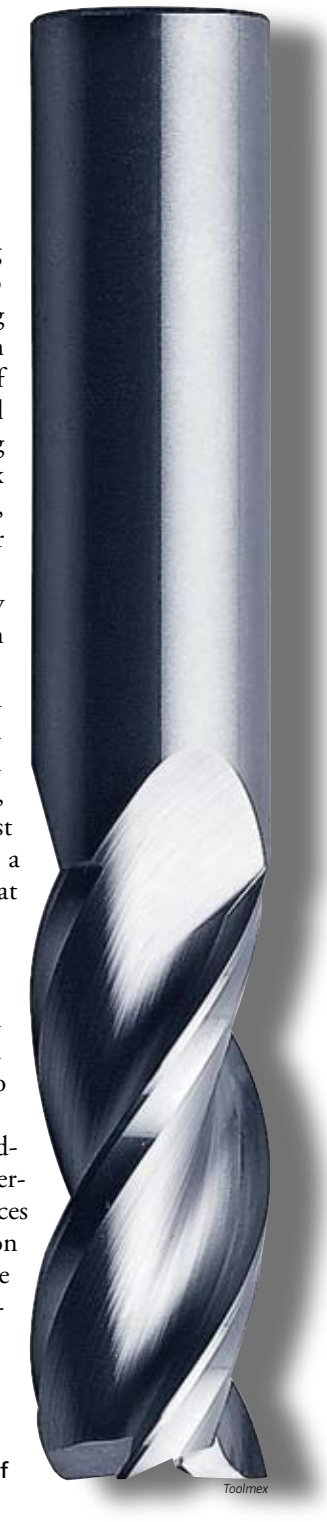
"A corner needs a variable-geometry endmill to allow it to be cut at high speed," Delleman said.

He added that many toolmakers grind special geometries that affect how an endmill should be applied and how well it will work under particular conditions, but there is really no one tool that is best under all circumstances. Consequently, a parts manufacturer should choose what works best for its application.

Designed for High Speed

An example of a solid-carbide endmill made specifically for HSM of aluminum workpieces is the Jabro endmill from Seco Tools Inc., Warren, Mich.

According to Eric Gardner, Seco product manager–Jabro tools, an endmill generally can be more free cutting if it reduces vibration and much of reducing vibration is about controlling chip flow. Thus, the Jabro endmill includes features to maximize chip evacuation.



Toolmex

Polished flutes and variable helix angles are two features that help make Toolmex's Mako endmills suitable for high-speed machining of aluminum workpieces.

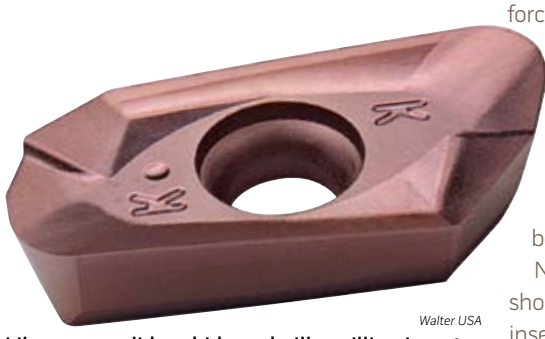
Learn more about high-speed milling

Read more commentary on high-speed milling of aluminum workpieces by visiting Joseph L. Hazelton's Web log in the CTE Community section online at www.ctemag.com.

High-speed endmilling with inserts

MILLING TOOLS WITH INDEXABLE inserts can also be used in high-speed endmilling of aluminum workpieces.

An insert can be coated or uncoated. However, like a solid-carbide endmill, the insert needs a sharp, high-positive cutting edge and a ground periphery to reduce cutting forces and vibration, according to Patrick Nehls, Walter USA's product manager—indexable tools.



Walter USA

Like many solid-carbide endmills, milling inserts, including a number of Walter's ZDGT inserts, can also be applied to vibration-free, high-speed machining of aluminum workpieces.

"Generally, the softer the material, the higher positive and sharper the cutting edge should be," he said.

Nehls added that hydraulic chucks should be used to hold indexable-insert endmills because that type of chuck can accommodate the tool assembly's shank, which is at least 1" in diameter.

Lastly, an indexable milling tool should be well balanced. According to Nehls, an endmill's shank can contribute to this balance by being cylindrical and having no flats.

"The more symmetrical the basic tool is, the better the chance to properly balance the assembled tool," he said. "When the tool is well balanced, there is less vibration at the high cutting speeds normally encountered when milling aluminum."

—J.L. Hazelton

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Jabro endmills have a thin core, deep flutes and a 25° helix angle. Gardner described this angle as shallow compared with conventional endmills, which have helix angles of at least 30°. However, he said the Jabro's lower helix angle reduces cutting forces, which helps with chip evacuation.

In contrast, the endmill's rake angle is 20°, which Gardner described as "quite high." The angle is that high so it permits sufficient chip room in front of the cutting edge to aid chip evacuation.

According to Gardner, the endmill's ability to evacuate chips allows it to handle high chip loads, which in turn allows it to handle large, full-channel cuts and achieve higher metal-removal rates than a general-purpose endmill.

A general-purpose endmill, meanwhile, isn't designed to operate at the same feed rate as a Jabro endmill. Also, a conventional design is not going to evacuate chips as effectively. "It's all

Seco Tools

Controlling chip flow reduces vibration in high-speed endmilling of aluminum workpieces, so Seco's Jabro solid-carbide endmill includes a thin core and deep flutes to maximize chip evacuation.

about chip flow," Gardner said.

Also, the Jabro endmill's relief angle has a proprietary geometry, which Gardner said contributes to the endmill's free cutting. "It avoids pulling of the tool into the material, keeping the endmill and the cut very stable," he said.

Moreover, Jabro endmills are made from submicrograin tungsten carbide. "It does make it a very dense and stable tool," Gardner said.

Travis Shatzley described the Jabro endmills' carbide as "very, very dense." Shatzley is a programmer, setup and lead man at machine shop Metlfab Inc., Frederick, Md., which uses Jabro endmills in its HSM of aluminum workpieces.

Shatzley said a Jabro endmill is noticeably heavier than a conventional endmill of the same size. "There is a major weight difference that you can feel in your hand."

Milling Deep

Metlfab became familiar with the Jabro endmill years ago, when the shop was having trouble with vibration while applying long endmills in high-speed machining of large, deep aluminum housings for a ground-to-air communications application.

The housings mainly ranged from 2" to 4" in depth, but some were 5" to 6" deep. Shatzley said the housings were more often around 4" deep and the most common workpiece dimensions were 8"×13"×4" and 10"×15"×4".

Metlfab solved its vibration problem through a combination of high-speed milling machines, Jabro endmills and experimenting with feeds, speeds and DOCs. Consequently, the shop can run its Jabro endmills at spindle speeds of up to 36,000 rpm and feed rates of 150 to 450 ipm, thereby reducing cutting times. "It's true high-speed milling," Shatzley said.

Ending Bad Vibration

The Jabro endmill aided a second machine shop in its high-speed milling of aluminum workpieces.

In July '07, parts manufacturer GTI, Powder Springs, Ga., started to machine a new job consisting of 45 part numbers, a group of aluminum structural parts for application in aerospace.

GTI has machined aluminum parts for 12 years, so it has experience with high-speed milling and dealing with vibration. "We fight with vibration all the time," said Mike Galinac, GTI's general manager.

Manufacturing the new job's parts in satisfactory cycle times, however, required the machine shop to use higher

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milling speeds. "We had to start moving the tools faster to get our times down," Galinac said. Immediately, though, the higher speeds created too much vibration.

By the fall, GTI started to apply Jabro endmills to the workpieces. The tools allowed the shop to mill deeper and more quickly, enabling it to reduce its cycle times, in some cases by 50 percent, Galinac said.

While the endmills permitted faster machining, Galinac credited their toolholders with solving a vibration problem the shop encountered. He cited GTI's use of Schunk Tribos-R toolholders as an example, saying that series of holder includes a plasticlike membrane in the cavity for the tool, a membrane that dampens vibration.

According to Galinac, GTI reduced vibration to acceptable levels when applying its long endmills and eliminated it when running its short ones. He cited the reaches of four 12mm-dia. endmills to define what GTI conceives of as short, medium and long tools. The reaches are 30mm (short), 40mm (medium), 60mm (long) and 80mm (long).

Also, the Tribos toolholders include a series with thin necks, a useful feature for GTI. "We have to get in such tight areas," Galinac said.

Galinac defined a thin-neck holder as having a 16mm to 20mm diameter. That range is available in the Schunk Tribos-S series toolholders, which GTI uses in its high-speed endmilling of aluminum workpieces. The shop uses the S series holders for endmills with 1mm to 8mm cutting diameters and uses larger S series holders or Tribos-R holders for endmills with 10mm to 20mm cutting diameters.

As for GTI's tight areas, those are instances in which the shop has to bring an endmill close to a part's fixtures or to its other features. The thin-neck toolholders allow the shop to maximize clearance relative to the fixtures and features to avoid accidental contact during machining.

About machining the 45 part numbers, Galinac said, "That was the job that definitely put us to the test."

It was fortunate that GTI solved its

contributors

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vibration problem in that test. In March, its customer increased the job by another 60 part numbers.

Cutting Strategies

Naturally, endmills for HSM should be run at higher feed rates, but there is a practical reason for doing so beyond higher productivity. Higher feed rates mean greater chip loads, which—up to a point—stabilize the endmill.

For example, if the load is too low, a milling insert will rub against the workpiece, creating heat and damaging the cutting edge. However, if the load is too high, the chips can become too large, preventing chip evacuation. This creates high forces on the tool, which may lead to tool failure.

"The proper load will have a stabilizing effect on the tool," said Patrick Nehls, product manager–indexable tools for Walter USA Inc., Waukesha, Wis.

Also, Metlfab's Shatzley recommended climb milling rather than conventional milling when finishing aluminum workpieces via high-speed milling. He said the technique avoids unnecessary pressure on the endmill.

Staying Balanced

An endmill's best performance during high-speed milling of aluminum workpieces, however, involves more than cutting strategies and the tool's cutting edges, flutes and other milling-zone features.

Having credited toolholders with solving the vibration problem in a new aerospace job, GTI's Galinac added that an endmill's toolholder should also be balanced to keep it from "wobbling" at the spindle end.

The toolholder may be balanced by its manufacturer, so it arrives at a machine shop not needing balancing itself. For example, GTI's toolholders include ones balanced by their manufacturer for up to 25,000 rpm.

However, a balanced toolholder doesn't necessarily mean a balanced tool assembly. Putting a tool in the holder, for example, can introduce an amount of unbalance in the assembly, so a machine shop may want to have a toolmaker or other business balance a whole assembly, or the shop may decide to balance the assembly itself if it has its own balancing machine.

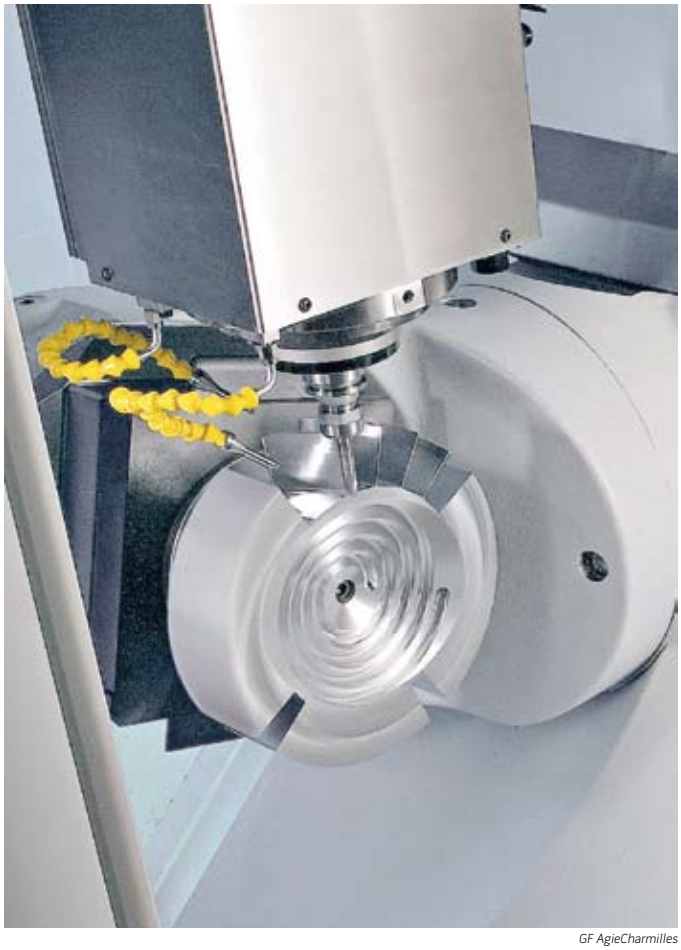
Also, when high-speed milling exceeds a certain spindle speed, like 25,000 rpm, the cutting tool assembly may require additional balancing.

Moreover, a tool assembly's overhang should be kept as short as possible for its application because the further an endmill extends, the less rigid it becomes and the greater the chance of vibration.

Holding Tight and Right

As part of the tool assembly, toolholders must have sufficient clamping force when used in high-speed milling of aluminum workpieces to dampen vibration.

However, sufficient force may be sometimes difficult to obtain on a thin-neck toolholder because of the holder's thin wall. "You're only going to be able to exert so much force," Galinac said. To obtain more clamping force, he recommended



GF AgieCharmilles

The cutting tool is only one factor among several that permits machine shops to perform vibration-free, high-speed endmilling of aluminum workpieces. Other factors include the toolholder, machine tool and the feeds, speeds and DOCs.

a machine shop substitute its initial holder with a collet or with a larger holder and a reduction sleeve when wanting to apply a thin-shaft endmill.

Seco's Gardner recommended a shrink-fit toolholder. "It's a one-piece design with a close tolerance," he said.

GTI also favors toolholders that exert pressure from multiple points. The machine shop often uses Tribos toolholders when high-speed milling aluminum workpieces because they apply enough clamping force in GTI's applications that the tools aren't pulled out while milling.

The clamping force comes from the toolholder's trioval polygon opening, which exerts pressure on three points equally spaced along the circumference of an endmill's round shank.

However, a shop needs a separate benchtop clamping device to insert an endmill into a Schunk Tribos toolholder. The device features a metal ring into which a Tribos toolholder is placed. With its pump activated, the device exerts pressure through the ring onto the toolholder's OD. Its ID, the polygon opening, deforms into a circle. A machinist inserts a round-shank tool, deactivates the pump and the opening returns to its trioval shape, so the tool is now held by three pressure points equally spaced around its circumference.

"It's like a shrink-fit, without being a shrink-fit," Galinac said.

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Gardner cautioned against collet chucks and hydraulic toolholders for solid-carbide endmills. He said vibration can occur with hydraulic toolholders because they generally can't withstand the radial forces of high-speed roughing. Consequently, to avoid vibration, the endmill's cut would have to be lighter with a hydraulic toolholder than with a shrink-fit one. "You wouldn't be able to take as heavy a cut," Gardner said.

As for collet chucks, Gardner said they usually have less clamping force than hydraulic toolholders. "We were able to suck the tool out of a very high-quality collet system," he said.

GTI does use collets to hold endmills during high-speed machining of aluminum workpieces, but Galinac said those endmills are only 10mm or smaller in diameter. Otherwise, the shop risks a tool being pulled out of its holder.

Ultimately, minimizing or eliminating vibration is a key to high-speed milling of aluminum workpieces, to achieving the greatest milling productivity.

"Surface speeds don't matter," Gardner said. He explained that the fastest surface speed may not be the most productive because that speed may create too much vibration, hindering productivity. He also said if a machinist slowed down his endmill to reduce or eliminate vibration, then a surface speed that's 15 percent less than the endmill's maximum might result in 100 percent more productivity.

"Maximum metal removal will occur at stable spindle speeds," Gardner said. CTE

Ultimately, minimizing or eliminating vibration is a key to high-speed milling of aluminum workpieces, to achieving the greatest milling productivity. 'Surface speeds don't matter. Maximum metal removal will occur at stable spindle speeds.'

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