By Kip Hanson,
Contributing Editor

Researchers seek to monitor the 'unmonitorable'

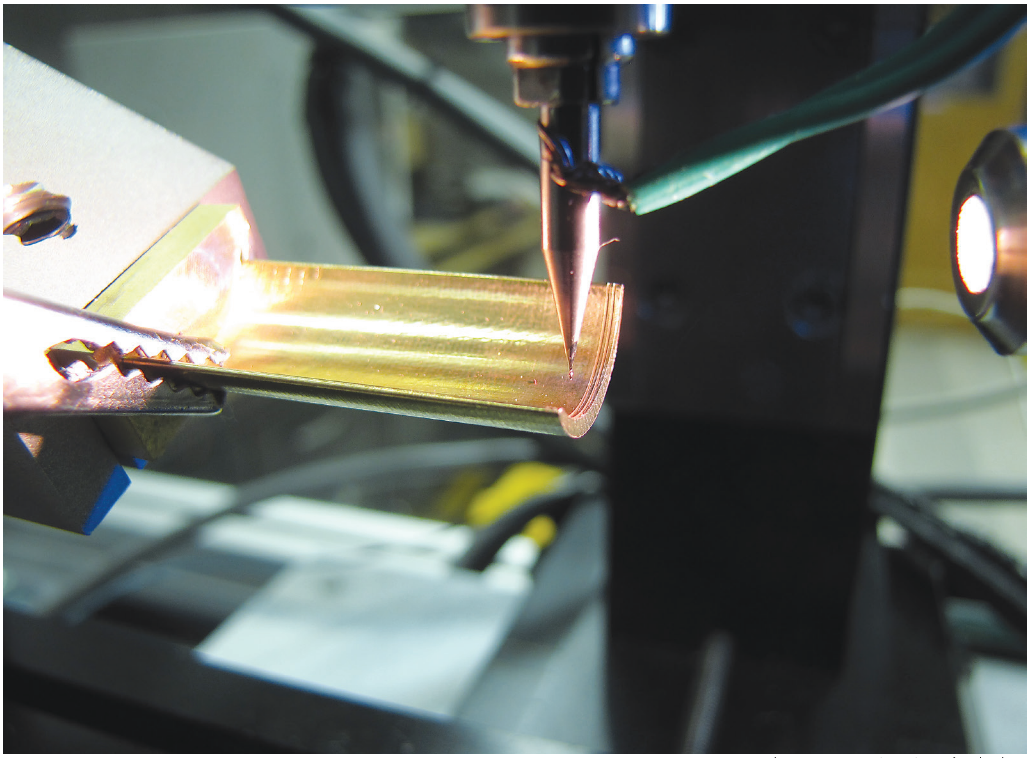
Keeping an eye on the cutting tools in most CNC machine tools is a straightforward exercise. Get a touch probe, write a few programs and you're off to the races. You might also opt for an acoustic tool-breakage system, spindle and axial cutting force measurement, or laser-based tool measurement that checks tool length and diameter on the fly. Barring that, even a trained ear, or a quick look at the machined part surface, is often an adequate defense against premature tool failure.

All this assumes you work in the macro world, however. Cut parts with tools smaller than a sewing needle and currently available commercial monitoring systems are useless. But, as micropart production and the use of microtools surges, researchers are trying to monitor the "unmonitorable."

Earlier this year, M. Prakash and M. Kantha Babu at Anna University, in Chennai, India, published a study in which they used acoustic monitoring devices to "listen" for wear in 0.5mm-dia. cutting tools. They discovered "a strong relationship between the tool wear (flank wear) and acoustic emission (AE_{RMS}) signals, surface roughness (R_a) as well as chip morphology" when milling copper, aluminum and steel samples.

A 2011 study by Ogedengbe, Heinemann and Hinduja at the Federal University of Technology, Akure, Nigeria, suggests that spindle and axis-motor electrical current signals "possess characteristic trends that would be useful for monitoring tool wear progression in micromilling." A paper published in 2009 in the *Journal of Materials Processing Technology* described an experiment at the University of Calgary in which the signals from 3-axis force sensors, accelerometers and capacitance devices were compiled into a "neuro-fuzzy algorithm" that could "monitor micro-milling operations and provide warnings to an operator in order to minimize tool breakage and violation of part tolerances."

Closer to home, J. Rhett Mayor, associate



J. Rhett Mayor, Georgia Institute of Technology

Georgia Tech developed a microtool monitoring method that relies on electrical conductance to sense a tool's tip when touching off.

New frontiers in microtool measurement

While no microtool monitoring system is currently on the market, Marposs Corp. plans to change that with the introduction of its Vision Tool Setting system.

Sharad Mundra, product manager for Marposs' probing division, said the Auburn Hills, Mich., company's VTS system measures tool diameters as small as 10µm and is accurate to better than 2µm. Marposs SpA, based in Italy, developed VTS to meet the needs of ultraprecision machine tool builders. One of the main requirements of the OEMs was good repeatability and the ability to function in a harsh environment.

The VTS system uses a light emitter and CCD camera to measure a microtool in the machine while the tool is spinning. With its advanced image-processing technology, the VTS system provides 0.1µm resolution and measures tools from 10µm to 40mm in diameter. And, reportedly, you don't need to slow the spindle down to check the tool. "The concept is simple," Mundra said. "A CCD camera takes several snapshots per rotation, looking at the tool diameter, shape, runout and position. It does this in one tool-positioning cycle."

According to Marposs, the VTS system combines the advantages of mechanical and contactless tool setters. The tool is measured under real-life conditions, thus reducing presetting time and eliminating collision risks, and tool shape does not affect the measurement results.

–K. Hanson

Marposs

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professor of manufacturing at the Georgia Institute of Technology, has spent the last decade researching micromachining. Like his colleagues overseas, he agreed that monitoring small tools is a big challenge.

"With conventional machining, you'll typically hear a change or feel vibration when the tool wears," he said. "With microtools, the spindle is turning so fast and the tool is so small that you won't get any feedback until it's too late."

Because of this, Mayor and a team at Georgia Tech worked out a novel microtool monitoring method. The team developed a system that relied on electrical conductance to sense a tool's tip when touching off. "What we focused on initially was how do you register a cutter measuring 30µm in diameter to a workpiece without breaking it?"

The team mounted a rotary bushing on a toolholder, then connected one end of an electrical circuit to the bushing and the other to the workpiece. By sending a small amount of current through the tool, they could immediately tell when the cutter made contact with the workpiece.

"It's only a few milliamps, but as soon as the tool touches, it completes the circuit," said Mayor. "Similarly, the current stops when the tool breaks. It's like a continuity check with a multimeter. The high-speed ceramic spindle bearings work in our favor, since they isolate the tool from the rest of the machine."

Mayor's group quickly realized something else. While monitoring the circuit for tool breakage, they noticed subtle changes in the current flow. "We started studying the current signatures and found there's a slight shift in the sine wave just before the tool breaks." After they knew what to expect, they could predict tool failure … sort of.

As Mayor explained, microtools deteriorate quickly and fail catastrophically. "The goal here was a predictive tool. We're not quite there yet. We can observe trends and see that as the tool deteriorates, the contact frequency increases a few percentage points. However, the time between decay and complete failure is too short for predictive analysis at this point."

Still, Mayor's strategy gives the lab valuable information. Without it, the researchers might break a 50µm-dia. tool and not know it until the cycle ended. "It's become our alert system. We can't really measure the wear, but we know there's still a tool there. If there's a problem, we'll receive an e-mail that says, 'Hey, your tool just broke.' "

Mayor said that in order to commercialize the system, more research would be required.

Building a new handbook

Frank Pfefferkorn, associate professor of mechanical engineering at the University of Wisconsin-Madison, takes a different approach. Using a piezoelectric force dynamometer from Kistler Instrument Corp., Amherst, N.Y., he can monitor minute changes to the cutting force … sort of.

"It's a great instrument, but I don't know how useful one would be in a real-world application," he said. The device costs around $30,000, making it more suited to lab work. And, there are issues with measuring forces accurately when you're spinning a microtool at 80,000 rpm. "We can usually tell when an event occurs," said Pfefferkorn. "When a coating begins to delaminate, for example, we see forces go up, but that jump could also be caused by something else."

Despite this high-tech capability, most of Pfefferkorn's work on tool monitoring is more pragmatic. He and his colleagues are on a mission to build cutting models and tool-life data for those brave souls who machine microparts. "You can't look up in a handbook somewhere how long will it take to run [a certain] part, or what it's going to cost. Our hope is to bring this information to the micro realm, so people can calculate with some level of certainty what tool life and production rates will be under certain conditions."

M. Kantha Babu, Anna University

At these facilities at Anna University, researchers used acoustic monitoring devices to "listen" for wear in 0.5mm-dia. cutting tools.

To this end, Pfefferkorn uses a scanning electron microscope as well as white-light optics and imaging software from Alicona Corp. to construct 3-D models of worn cutters from 10µm to 300µm in diameter.

What Pfefferkorn sees under the microscope provides clues to microtool failure: coating delamination, edge wear, and minute changes in tool diameter and shape. "These are not things we would see in the macro world, nor worry about. When you have whole grains of carbide coming off a tool this size, it really changes the geometry."

One possible outcome of UW-Madison's work is a new set of standards for microtool wear—similar to those that exist for macrotools. "We hope to better describe the dominant wear mechanisms and explain why microtools fail," said Pfefferkorn. µ

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