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Rather than develop an apprenticeship program in-house, some machine tool builders turn to established programs, such as the ICATT program.

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In part two of this two-episode report, the Grinding Doc runs a few numbers to determine a suitable overlap ratio.

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“Star Trek” meets machining with United Grinding Group’s “Cyber Chair,” which remotely monitored about 20 machines exhibited at the company’s Grinding Symposium in Thun, Switzerland. The futuristic chair showcased the first products from United Grinding’s digital solutions: production, service and remote monitoring applications. See this and more on CTE social media.
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Coated cutting tools are so abundant today that it is almost hard for me to believe there was a time during my life when only uncoated tools were applied to cut metal. It wasn’t until the late 1960s that the first coating emerged.

Paging through the bound back issues of *Cutting Tool Engineering* from around that time, the first reference to a cutting tool coating that I found was in the July/August 1970 issue’s Product of the Month department. The product was the KC75 titanium carbide-coated insert grade from Latrobe, Pennsylvania-based Kennametal Inc. The article stated that the chief advantage of the 5µm- to 7.6µm-thick chemical vapor deposition coating was that it combined the properties of both tungsten carbide and titanium carbide to significantly reduce two major forms of cutting edge deterioration: heat produced by friction as the chip moved over the face of the tool and heat produced by friction as the workpiece moved past the cutting edge.

In addition, the product report included two short case studies that described the advantages of these coated inserts. In one, General Hydraulics Inc., Bucyrus, Ohio, was able to increase cutting speed from 495 to 840 sfm and get 21 pieces per edge versus six to eight with an uncoated carbide insert when turning C-1212 hot rolled steel.

About 20 years later, toolmakers introduced physical vapor deposition-coated cutters. With a thickness of about 3µm, these coatings were and are more effective when coating sharp cutting edges. PVD coatings have other advantages compared with CVD ones, and therefore most tool coatings are deposited via the physical vapor process.

About a year ago, toolmaker Superior Tool Service Inc., Wichita, Kansas, invested $2.2 million in coating equipment and launched an in-house PVD coating division, STS Coatings. See Page 52 for my article about the company’s coating services.

STS specializes in round cutting tools, where PVD dominates. “We don’t see much CVD on round tools,” said President Clint Whitney. “It’s mostly on inserts and for special applications.”

Another article about tool coatings appears on Page 46. Penned by technical writer Del Williams, the article covers specialty coatings, such as high-performance PVD and diamond plasma-assisted CVD coatings, for machining nonferrous materials. Curiously, although scientists in the Soviet Union began researching diamond coatings in 1977, they didn’t become commercially available until the early 1990s.

Completing this issue’s tool coatings “triptych” is the Look-Ahead column on Page 68 by contributing writer Robert Weinstein. It covers the work of researchers at Linköping University in Sweden who are trying to extend the life of TiAlN-coated tools.

When it comes to coatings, CTE keeps you covered.

**about the author**

Alan Richter is editor of CTE. Contact him at 847-714-0175 or alanr@ctemedia.com.
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KEEPING THE FAMILY TOGETHER

The opportunity to work for a successful family business can be rewarding, and lots of machine shops are great examples. Being in this industry has introduced me to a variety of family-owned operations that are impressive and even cool. What a country.

Such success also comes with challenges and disagreements when dealing with sensitive issues. Occasionally, relationships are tested. Family members share interests and ownership. These intertwined lives result in unique situations. For better or worse, company business impacts lives at home and work, and it’s not for everyone.

When issues occur among normal co-workers, they are not related, don’t live together and don’t have to see each other after work. But family is different, and staying together through thick and thin is a priority.

My family can relate to all this as we’ve been working together for years. First, it was my parents for a long time. Then, I came along in 1992, followed by my brothers in 2008. Our parents eventually retired but remain involved and help as needed. In all our working history together and throughout many ups and downs, the biggest test of the family work bond was encountered during our most recent downturn of 2015 to 2018. Several factors made this test more difficult, including a market downturn that was the worst in years and the fact that we were now all working at the family business and dependent on it for income. In previous years, it was only my parents, then later me as well. Until my brothers were with us, their incomes and livelihoods didn’t totally depend on the family shop. They were in school or had other jobs.

Fast forward to 2015 with all of us working together, all with growing families of our own and reliant on the family shop for everything. Combine that with our worst market crash in 25 years, and you have a dicey situation, a much different set of circumstances. As president and the oldest member of my generation, it was my responsibility to navigate the company through this tough period, as well as to ensure that my family members had incomes, insurance and employment. It was a stressful era to say the least. We spent time together outside work anyway, but our conversations about business and survival were frequent, often draining and stressful and occasionally argumentative. When business is great and a company is profitable, it’s much easier to work together and get along. It’s when conditions are down that a family can be pushed to its limit.

Throughout it all, we stuck it out and remained strongly intact. I’ve pondered why we made it through compared with others who haven’t. I believe we succeeded for a few reasons that perhaps could help other family shops. First, we constantly communicated, exchanged ideas and kept each other informed about conditions. We shared the pain of cuts and loss of income. We all pitched in and took on new duties, covering for laid-off employees. Our parents became more involved again, using their experience to advise and help deal with sensitive issues involving money and income. The bottom line was that we valued our family relationships and knew we had to stick together.

It wasn’t easy, but incredibly valuable lessons in business and life resulted. We remain a tight family and still hang out. It’s a wonderful thing.

about the author
Keith Jennings is president of Tomball, Texas-based Crow Corp., a family-owned company focused on machining, metal fabrication and metal stamping. Contact him at jennings4176@yahoo.com.
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No doubt you’ve been hearing a lot about artificial intelligence lately. But you may not have heard about the impact AI is having on machining operations—and how that impact may grow in the near future.

Today, most AI applications in machining focus on condition monitoring and predictive maintenance, said Jörg Krüger, head of the industrial automation technology department at the Technical University of Berlin in Germany.

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“These fields seem to be most popular because the algorithms for pattern recognition are easiest to adapt to data from sensors” that measure process values, such as force and acceleration, he said. “These are also applications where machine learning’s potential for value creation is most obvious for machine tools.”

For machining processes, AI algorithms can create value by monitoring the wear of key components like cutting tools and bearings and predicting when they need replacement. Such applications date back at least 30 years, when the first AI algorithms were installed to process signals from cutting operations, such as turning and milling, said Krüger, who researched machining AI as early as 1991.

More recent developments in this area include those announced by Ditzingen, Germany-based Trumpf GmbH + Co. KG, which plans to employ AI to improve the performance of its laser-cutting machines. One example will affect the unload-
The unit of Trumpf’s TruLaser Center 7030 repeats part removal cycles to get the task right. The retry data will be fed to a machine learning system to improve the unloading process in the future.

In real time, AI will not play a role in the retry approaches, which follow a scripted sequence. But Trumpf plans to collect unloading data from TruLaser Center 7030 machines in the field, then feed this information to a machine learning system to create more effective unloading strategies for future use.

In research settings, AI shows promise in other machining-related applications, said Krüger, who analyzes AI’s industrial potential for the German Academic Society for Production Engineering. One of these applications is the automated prediction of surface quality by neural networks, which are computer systems modeled on the human brain and nervous system. Surface quality predictions come from...
cutting parameters. The parameters are automatically identified by a neural network based on signals received from drives or information from a CNC. When a cutting operation starts, data is collected at a high sampling rate and the neural network learns the process in a few milliseconds, he said.

No matter what advances AI researchers make, however, he pointed out that the success of AI in machining operations depends on the operators who must interpret the predictions of AI algorithms and set the right parameters for the production processes in which the algorithms operate. Although he sees rapid progress in the development of AI algorithms, he does not see anything close to corresponding progress in operator education about AI. “Until this gap is closed,” he said, “I don’t think the huge progress in research can be transferred to real applications in most cases.”

“Condition monitoring and predictive maintenance are ‘where machine learning’s potential for value creation is most obvious for machine tools.’”

Jörg Krüger
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Efficiently Remove Material

By David Conigliaro, CNC Software Inc.

The evolution of efficiently removing material has basically unfolded like this:

Traditional machining. We used the speeds and feeds recommended in catalogs from cutting tool manufacturers. We cut a 50% step-over as a rule of thumb, and while maybe it wasn’t the most efficient process in the world, we didn’t know the difference.

Radial chip thinning. We still used the machining parameters from the cutting tool catalogs, yet we were also able to increase the feed rates and metal removal rates when stepping over less than 50% of the tool diameter. We began to increase productivity—when we went in a straight line, that is. Fluctuations in tool load continued to limit productivity.

Dynamic Motion. This is where we have been for about 10 years. We started with the radial chip thinning principles and have been increasing feed rates, step-downs and removal rates. The cutting tool motion modifies dynamically to produce consistent, optimal chips—we call this constant chip load machining—and offers efficient cutting conditions regardless of workpiece geometry.

For several years, the Dynamic Motion application has proven itself again and again for those who have adopted these material-aware toolpaths. As always, we learn from customers who use our software in the real world day in, day out. They eagerly tell us about their successes and challenges. With each release of our software package, we tweak this or that based on their valuable feedback.

What we are hearing and addressing now is this: Many customers are becoming so comfortable with Dynamic Motion that they want to be as aggressive as possible, such as stepping down three or even four times the tool diameter. In many cases, that’s just fine. However, going around corners can be troublesome because the cutting tool tends to want to grab that edge. Then the metal can grab the tool, and the metal can bend. As such, we’re working on future technology in the Dynamic Motion engine to aid users who are trying to be very aggressive or those machining challenging materials.

Also, sometimes during milling, sharp, knife-edge corners are created simply by the way the tool moves around an area. Tall, skinny
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islands or peninsulas can be made accidentally. When the tool hits those, tool pressure might flex material away from the tool so when it comes around the other side, there’s more material in its path than expected. These tall, thin pieces of material can damage tools or cause other issues. The question now surrounds how we can provide alternative, safe measures and alleviate or even prevent this particular condition. Simulating processes with the software often reveals the trend, and the programmer can adjust the code to back off in certain areas. Furthermore, soon there will be other approaches to select in the software when the condition is recognized or likely to occur—for example, taking multiple-depth cuts in strategic areas at appropriate moments. Instead of stepping down three times the diameter in one cut, the programmer might choose to take it down one time the diameter three times around.

There could be other ways to address this, such as taking a software development course to predict conditions and automatically adjust processes to avoid them.

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CNC Software is working on future technology in Mastercam’s Dynamic Motion engine to aid users who are trying to be very aggressive or those machining challenging materials.
That would call for extreme computational complexity, but the feasibility of it is worth exploring.

The main point of any discussion about the evolution of efficient removal of material is that we certainly have come a long way in the past decade. I hope that every CNC programmer at every shop uses the latest tools available—and by “tools” I mean the latest toolpaths for roughing and finishing, along with advanced cutting tools. New cutting tools and toolpaths are often developed in conjunction with each other so users can take full advantage of the benefits: longer tool life; shorter cycle times; quicker programming; greater use of smaller, less expensive cutting tools; and less time required for finishing passes. In addition, with the trend of more manufacturing automation equipment being installed, there’s the benefit of running lights out with greater confidence.

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**about the author**

David Conigliaro is mill product line manager at CNC Software Inc., Tolland, Connecticut. For more information, call 800-228-2877 or visit www.mastercam.com.
Dear Doc: When cylindrical-plunge grinding ODs in hardened bearing steel with an aluminum-oxide wheel, I get thermal damage in the form of a white layer. To battle this burn, I’m going to redo our cooling system to get higher coolant velocities. What do you recommend?

The Doc Replies: My recommendation is this: Don’t bother. If you’re burning with bad cooling, you’ll burn with good cooling. For that OD grinding process, the coolant just doesn’t suck up enough heat to make a huge difference. You’re screwing up something else, and that’s why there’s burn.

There are two exceptions. First, if you’re burning because you’re loading the wheel, improved cooling—getting the coolant velocity close to the wheel velocity and aiming at the wheel-workpiece interface—will slow loading and perhaps delay the onset of burn. But unlike stainless steel and nickel-base alloys, bearing steel isn’t prone to severe loading. So I don’t think that bad cooling is the cause of the burn. The second exception is if you’re grinding with a 30° swivel and getting burn not on the OD but on the shoulder. Here, a dedicated, high-velocity nozzle to cool just the shoulder will reduce burn.

Using a wheel with too large of a grit size and dressing dull likely caused your OD burn. That’s the root cause of most of the burn in cylindrical-OD grinding that I see on shop floors—not bad cooling. Switch to a finer grit size, and dress sharper.

Dear Doc: The old-timer machinists at my shop say I should always dress and grind at the same wheel rpm. Are they right? If so, why?

The Doc Replies: Yes, you should try to grind and dress at the same rpm. Keep in mind that no wheel is perfectly balanced. So when a wheel is dressed, it pulls toward its heavy side. Imagine mounting a monster weight on just one side of a wheel. Now, imagine the centerline of the axis of rotation. When that wheel rotates during dressing, it will pull—and deflect—in the direction of the imbalance. Therefore, you’ll end up dressing deeper on its heavy side and less deep on its light side.

Now, your wheel is egg-shaped, and that is somewhat of a bad thing. But now when you grind, the wheel also will pull and deflect. And it will pull and deflect just the right amount to compensate for the “eggyness” of the wheel. But if you dress at a low rpm and grind at a higher one, your wheel will be only slightly egg-shaped from the low rpm dressing. Yet the wheel needs to be very egg-shaped during high-speed grinding.

So it’s best to dress and grind at the same rpm. Having said that, I’ve seen a lot of operations do just fine with a different rpm for dressing and grinding. That is because if the imbalance isn’t too bad, the spindle is very stiff or the tolerances aren’t too tight, you can survive with eggyness.

Dear Doc: I grind HSS and switched from pink alumina to Norton SG without much success. Why?

The Doc Replies: Because you’re grinding like a wimp. Pink alumina grit is friable, and Norton SG ceramic grit is tough. Be more aggressive by increasing the feed rate 25%, increasing the DOC 50% or decreasing the wheel speed 20%. Those are minimum recommendations. You probably should be even more aggressive. Tough grits need big forces to fracture them. Otherwise, they dull and burn.

about the author
Dr. Jeffrey Badger is an independent grinding consultant. For more information, visit www.TheGrindingDoc.com.
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Gearing Up

Make mill/turn lathes and multitask machines into gear-cutting workhorses.

By Kip Hanson

Perhaps you already own a multitask machine or a mill/turn lathe. Perhaps you’ve considered investing in one. Whatever the case, here’s yet another way that these machines can add value and flexibility to any job shop or discrete manufacturing company: gear hobbing.

Hobbing, like most gear-making operations, is a complex process. It uses a rotating drum-shaped cutter that, depending on the gear type, is either held parallel to the workpiece centerline or tipped at a slight angle. As the hob rotates, the machine is fed in the longitudinal axis into the workpiece, which rotates in the same direction but at a slower rpm. It is a single-pass process and, in terms of multitaskers and mill/turn lathes, primarily for external gear production.

Multi-Options

As you might have guessed, hobbing requires specialized cutting tools called hobs. It also demands accurate synchronization between the rotating workpiece and cutter and a working

Precise synchronization between the cutter and spindle is needed for any gear-machining operation.
knowledge of terms like root circle, pressure angle and module. This is why most shops have long subcontracted their gear-cutting needs to specialty houses, which have the equipment and tools necessary to perform such esoteric work.

Not anymore. Thanks to increasingly capable CNC machines and on-board programming software that tames even the gnarliest of gear forms, machine shops everywhere are performing their low-to medium-volume gear work in-house. One example is the Integrex AG series multitask machine from Mazak Corp. Mike Finn, senior applications development engineer, said the unit has several additional features that allow it to perform at a higher level than a standard Integrex.

“Because synchronization is critical when hobbing, we’ve added scale feedback to the Z-axis and the milling spindle,” he said. “There’s also a software package included on the Integrex AG machines titled Smooth Gear that lets you plug in values, such as diametral pitch, helix angle, pressure angle, cutter diameter and various gear form information, and the control will make the program for you. There are three modules to serve milling, hobbing and power skiving gear-cutting strategies.”

The Florence, Kentucky, machine builder isn’t alone. Hoffman Estates, Illinois-based DMG Mori USA Inc. offers similar gear-hobbing options, or Technology Cycles, on its NLX, CTX and NZX series lathes. Okuma America Corp., Charlotte, North Carolina, has gear packages for the company’s Multus multitask machines, as well as several of its mill/turn centers. Each uses the same hobs.

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‘Synchronization is critical when hobbing.’

about the author

Kip Hanson is a contributing writer for CTE. Contact him at 520-548-7328 or kip@kahmco.net.
Splines are among the many gear forms produced on multitask and mill/turn machines.

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found on any comparable hobbing machine, and each is capable of producing a variety of high-quality gears and splines, although at a slightly slower rate than a dedicated hobber.

**Why Go Slow?**

No machinist or shop owner likes to hear the words “slower rate” used in any sentence. And because users need dedicated tools anyway, many people might suggest that it makes more sense to purchase a used, far less expensive mechanical hobbing machine and stick it in a corner for occasional gear jobs rather than waste valuable multitasking time on a suboptimal machining process.

But not so fast. Multitask machines and mill/turn lathes are known for their ability to reduce part handling and work in process while increasing part quality, and geared parts are no exception. And as far as using a decades-old hobbing machine goes, it’s difficult enough to find qualified CNC machinists.

“Unless you have high production, you’re probably not going to buy a gear-cutting machine, new or used, because operating one calls for a very specialized skill set,” said Kevin Kraieski, senior application engineer at Okuma America. “Hobbing and indeed any kind of gear making is just so much easier on a multitasking machine. Also, companies generally want to integrate their processes into as few operations as possible. That’s the beauty of any multitasker or mill/turn.”

**Tooling Up**

Easy or not, there’s still plenty to know before embarking on any gear-making project. Robert Smiley, applications engineer at DMG Mori USA’s 5-Axis Center of Excellence in Hoffman Estates, said...
the company’s Technology Cycles make the programming aspect of hobbing easier. But he said there’s also machine-dependent tooling to consider.

“On a turret-based lathe,” he said, “you’ll need to purchase a special hob holder from someone like WTO or MD Tooling, which mounts on the turret and supports the cutter from both ends. For a multitasking machine, you would most likely opt for a spindle-mounted hob, probably using a Capto or HSK toolholder for the greatest rigidity.”

Compared with many machining processes, cutting forces are relatively high with hobbing. So it’s easy to argue that because a turret-mounted tool has dual support and therefore greater rigidity, this is the clear path. However, dual support means greater potential for interference with the toolholder, making the ends of a fairly expensive cutting tool harder to reach. Also, a turret-driven toolholder’s available torque is a fraction of the torque from a multitasker’s milling spindle,

‘Choosing a hob is really no different than choosing any other cutting tool.’

contributor

DMG Mori USA Inc.
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www.dmgmori.com

Dontyne Systems Ltd.
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www.dontynesystems.com

Mazak Corp.
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Gearing Up

reducing some of the rigidity gains.
Slightly greater tool deflection, however, is a fairly small price to pay for access to the entire length of the tool. This is the case with spindle-mounted hobs, which as a rule provide greater flexibility and tool life despite the need for less aggressive cutting parameters. Some machine tool builders have even added automatic shifting capabilities so tool wear can be spread across all the hob’s teeth.

Hob selection is also important. Tom Ware, product manager for gear tools at Star SU LLC, Hoffman Estates, said myriad hob styles, coatings, tooth geometries and base materials are available.

“Choosing a hob is really no different than choosing any other cutting tool in that you have to pick the appropriate substrate and coating based on the workpiece material, production quantities and budget,” he said. “Whichever tool you select, though, just know that each form is unique, and you will need a different hob for each gear.”

The Waiting Game

Buying multiple different hobs is a bummer for some people. Although a powder metal or HSS cutter is less expensive than one made of carbide, it still costs hundreds of dollars—sometimes way more. Aside from a generous tool budget, good planning is needed because lead times for even a standard hob are best measured in weeks and months.

An alternative to waiting for a special cutter is to mill the gear profile using a ballnose cutter, an oper-
ation that many machine tool builders support. This can be accomplished on a multitasker and some mill/turn machines, but it’s easy on a 5-axis machining center. Milling individual teeth in this manner, if the most flexible approach, does rank among the slowest of all gear production methods. Despite some apparent, though often negligible, drawbacks, growth in this area is high. Each machine builder source said it has seen great interest in hobbing in recent years, with hundreds of gear-making control packages sold. A variety of such packages and software programs are available, including gear hobbing; power skiving, which often is used for internal gears; and milling.
Aside from the control software, some builders offer probing cycles for in-process part measurement. This can be a big help to newcomers who are learning not only how to make gears but how to measure them. Properly executed, the gears produced on multitaskers and mill/turn centers are very accurate, with American Gear Manufacturers Association ratings in the range of eight to 10 (12 being highest).

**Take It to the Limit**
Mike Fish, co-director of Don-

Given the right machine, software and cutting tools, even complex parts like this one can be "done in one."

"Unless you specialize in gear making, it can be difficult to understand what effect even very small deviations in the manufacturing can have on gear accuracy," he said. "Based on the application, a gear's tooth form can vary, and micron-sized adjustments are often applied to optimize performance. This is why our company focused its efforts on a closed-loop system, one
that helps you design the gear; machine it precisely despite distortions, deflections and tool wear; and verify the results with the inspection machine.

The company’s Gear Production Suite or a similar software package is a necessity for people designing and producing their own gears, but part manufacturers might question the need and say that’s what the control option is for. Yet shops that arm themselves with the best tools possible are most successful, especially with a complex undertaking like gear making, said Rich Easley, North American business manager for Dontyne Systems.

“The real power behind a system like this is that it links the design process to manufacturing,” he said. “It offers offline simulations for various gear-making processes, including hobbing, grinding, shaping, shaving and skiving. It provides cutting paths and tool design functions for CNC machinery, as well as inspection files for gear-checking machines, CMMs and in-process probing systems. It can help a shop utilize their existing tooling to produce prototypes or small-batch gears quickly and at low cost and allows a CNC to produce very challenging gears—spiral bevels, for instance—rather than using dedicated equipment. And perhaps most importantly, it opens the door for anyone that wants to pursue additional gear-making opportunities.”

CTE
Automated data capture can boost production efficiency, but the machining industry has yet to embrace it.

By William Leventon

If a relatively inexpensive product could make a process more efficient, would you buy it? That’s exactly what’s being offered by developers of systems that automate the collection of key production data. But so far, most machining operations have been unwilling to ditch the pen and paper.

Sellers of automated monitoring products make a strong case when explaining why their technology is superior to manual data collection. For one thing, manually recorded information is not timely, said Jim Finnerty, product manager at Wintriss Controls Group LLC, Acton, Massachusetts.

“Nobody likes to manually enter data, so that’s often the last thing people do when they finish a job,” he said. “Or they don’t do it at all for a while until the boss calls them out. But if there’s an issue with the (process) and the information is available in or near real time, somebody would be able to do something about it on the fly.”

In addition, manually entered data will never be as accurate as automatically collected data due to the potential for transcription errors and faulty memories that can cause inaccurate entries if the data isn’t recorded immediately.

“In my experience auditing manual data capture processes, they’re at best 40% accurate,” said Adrian Pask, vice president of international development at Vorne Industries Inc., Itasca, Illinois.

Inaccurate data entries aren’t always unintentional. Regardless of whether it’s true, some machine operators might believe that their performance will be judged by the process
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data collected, Finnerty said. “If that’s their feeling and they are manually recording data, they may not include unsatisfactory information, even if it’s not their fault,” he said.

So when Wintriss Controls Group installs automated data collection systems, customers often discover they have a lot more downtime than they believed, Finnerty said. He also said they frequently find that the causes of downtime are not necessarily due to the operator.

In a best-case scenario, Pask said people charged with monitoring and recording process data may be able to spot and get a response to a machine-related issue that causes a major loss in productivity.

“Automation Anomaly

At this shop, each milling machine has a ShopFloorConnect machine interface.

“But if you had three-minute stops that affected you a hundred times in a day, are people likely to see that?” he asked. “My contention is that if they’re not aggregating the data automatically, the answer is no.”

Automation Implementation

Some automatic data collection systems communicate directly with the machine control to get process information. Finnerty said the downside to that arrangement is that connecting the system to a machine becomes a major engineering project that can include writing code and modifying the controllers. Complicating matters further is that most machining operations employ a mix of different machines with a variety of controls, some of which may not allow connection to a
‘Nobody likes to manually enter data.’

So Wintriss Controls Group developed a data collection system called ShopFloorConnect that includes software and a dedicated machine interface, which Finnerty describes as a data collection device. ShopFloorConnect has a small color touch screen that can connect to any machine. To do its job, the device needs just a couple of simple signals from a machine: one that tells it when the machine is running and not running and another that tells it when the machine has completed a part or cycle. With those two inputs, the device can automatically collect production counts and other data related to efficiency.

In addition to the machine connection, the device connects to a server via an existing wired or wireless network. The server collects production data and makes it available in real time to a web browser or another interface. Flat-screen displays showing the collected data can be placed around the plant or on each machine. The data also goes into a database so it’s available for the creation of reports and tables.

If a machine is down, a menu designed by the user pops up on the touch screen and the operator can select a reason why the machine isn’t running. Users can require operators to do this by enabling an additional feature that inhibits machine operation until a selection is made. The device can also scan employee badges so it can identify who was running a machine at a given time.

When the operator selects a reason for downtime, the system can automatically send text or email alerts to appropriate individuals. Automatic alerts can also be sent at other points in the process—for example, at the beginning or end of a job or when a certain part count is reached.

As is the case with ShopFloorConnect, Vorne Industries’ XL Productivity Appliance doesn’t

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**about the author**

William Leventon is a contributing writer for CTE. Contact him at 609-926-6447 or wleventon@gmail.com.

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normally require the installation of sensors.

Instead, “we look for an existing sensor or relay that can give us an electrical pulse every time the machine cycles or makes a part,” Pask said.

XL counts these pulses to determine the number of machine cycles in a certain period of time. The device also measures the time between pulses and compares these two pieces of information with the user’s production standards to determine how well the process is running.

Automatically collected production data is often used to determine overall equipment effectiveness, the percentage of manufacturing time that is productive. OEE can be calculated by multiplying numbers representing three factors: quality, performance and availability. An OEE score of 100% means that a manufacturer is making only good parts (100% quality) as fast as possible (100% performance) with no process stop time (100% availability).

ShopFloorConnect automatically collects the data necessary to determine quality and availability. Performance, however, is entirely dependent on the part, Finnerty said. Therefore, a separate ideal production rate for each part is entered into the system. During the production of a particular part, the system applies the appropriate ideal production rate to the machine.

“This lets us calculate a very accurate version of OEE regardless of what the machine is doing and how long it does it,” he said.

New and Next

Automated data collection technology is not new, but there have been recent developments. Vorne Industries, for example, is using the cloud to distribute updates to its XL software.

Another firm, Memex Inc., Burlington, Ontario, is adding pattern matching to its Merlin Tempus data collection software.

**Automation Anomaly**

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**New and Next**

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**Contributors**

**Memex Inc.**

866-573-3895 ● www.memexoee.com

**Vorne Industries Inc.**

877-767-5326 ● www.vorne.com

**Wintriss Controls Group LLC**

800-586-8324 ● www.wintriss.com/sfc
“Since we are tracking everything, we can spot certain patterns before the operational management team sees them,” said President and CEO David McPhail. “Then alerts are automatically sent to people who need to know that certain things are happening.”

These could inform shop personnel about tool breakage, for example, or a machine that’s not running at the specified performance rate.

McPhail said the next frontier in the development of automatic data-gathering software is to marry the power of artificial intelligence with the information being collected.

“The XL Productivity Appliance tracks top losses, the main reason for reduced productivity.

“That will allow our products to predict certain scenarios in which performance will not be what it should be and then recommend to operators and management teams what should be done about it,” he said.

Uncommon in Machining

Although Memex’s product has been on the market for more than 11 years, McPhail estimates that at least 95% of machining companies haven’t automated their data collection processes. Pask and Finnerty also report a lack of enthusiasm for automated data collection products in the machining community as a whole.

Pask believes that many machine shops conclude they won’t benefit enough from the technology because of the nature of their work. The focus on material costs tends to be greater than the focus on time in low-volume, high-mix environments, he said.

“If you are making a single piece and it takes nine hours,” he said, “the value of that piece has much more to do with materials and material loss than (production) time.”

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As for machining operations that could benefit greatly from increased production efficiency, Finnerty insists they’re not being put off by the cost of automated data collection. He said the price tag for a typical 20-machine ShopFloorConnect package is under $60,000, not including installation costs, and the return on investment can be as soon as six weeks.

Rather than not having the budget for automated data gathering, he believes that many machining firms might be holding back because of implementation considerations.

“The entire plant should support and implement it,” Finnerty said. In particular, “the operators need to learn a different interface, and they have to be assured that this isn’t being put in to be Big Brother. On the contrary, ShopFloorConnect is very easy to install and can be up and running within two weeks.”

McPhail, who puts the payback period for his company’s technology at four months on average, said one of the biggest impediments to adoption is that many manufacturers wrongly believe they are already efficient. While a world-class OEE score is about 85% (0.95 for quality × 0.95 for performance × 0.95 for availability × 100), most manufacturers using manual data collection methods are actually at 35% to 40%, he said.

“But they think they’re much better because they don’t have any data to prove otherwise,” he said. “So there is a huge disconnect between perception and reality.”
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Because machine tools repeatedly remove material, frequently at high spindle speeds, to shape a workpiece, carbide cutting tools are often applied instead of HSS ones to retain a sharp cutting edge and extend tool life. However, when machining highly abrasive materials, such as carbon fiber-reinforced polymer, glass fiber-reinforced plastic, graphite, aluminum alloys or ceramics, even carbide tools can rapidly wear.

In these cases, further hardening carbide cutters with specialty coatings can significantly improve wear resistance and service life. For extremely expensive cutting tools, this not only reduces costs but shortens cycle times. These coatings come in a variety of types, from physical vapor deposition coatings to proprietary diamond coatings.

Greater Abrasion Protection

In a growing number of industries, including automotive and aerospace, manufacturers continue to place more emphasis on design and weight reduction. Designers subsequently increasingly use composite fiber-reinforced plastics in many parts, but these composites are exceedingly rough on cutting tools.

“The problem with the carbon and graphite fibers is that they are very high strength and extremely abrasive,” said Volker Derflinger, senior manager at Balzers, Liechtenstein-based Oerlikon Balzers, which has produced coatings for components and tools for more than 30 years. “For cutting tools to withstand heavy wear, it needs a specialty coating with a very high resistance to abrasion.”

In industries like automotive that require strong, lightweight materials, parts are also made of aluminum-silicon alloys. However, the higher the silicon content, the more abrasive the material.

“With aluminum-silicon alloys, there are very hard silicon particles embedded in the aluminum,”
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Derflinger said. “When you have to cut the material, the silicon content is extremely abrasive and can rip up the carbide tool. Even tooling with typical protective hard coatings can degrade very quickly.” When it comes to machining very abrasive materials, uncoated carbide tools experience accelerated wear. To increase tool life, high-performance coatings provide a vital protective barrier. He said the ideal coating would have a very hard, protective surface that simultaneously maintains the sharp cutting edges that enable clean, precise cuts while boosting productivity.

PVD Coatings

One coating type increasingly being utilized in these industries is strong, nonhazardous PVD. PVD describes a variety of vacuum deposition methods that can deposit thin coatings. The process typically coats tools and components at relatively low temperatures from 150° to 500° C, which avoids altering the fundamental material properties. Among the PVD options are several carbon-based coatings that provide a unique combination of extreme surface hardness and low friction coefficient properties. One example, Balinit Hard Carbon by Oerlikon Balzers, is suitable for machining nonferrous materials, including aluminum alloys with up to 12% silicon content.

“The Hard Carbon coating works on CFRP and GFRP but only when the fiber content is on the lower side,” Derflinger said. “The more fiber content, the more abrasive the material is, and then you need an even harder coating.”

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about the author

Del Williams is a technical writer in Torrance, California. He writes about health, business, technology and education and has a Master of Arts in English from California State University, Dominguez Hills.
The Balinit Hard Carbon coating has high hardness—40 to 50 gigapascals—making it appropriate for applications that require enhanced wear protection. In addition, the thin, smooth application helps maintain sharp cutting edges. For example, at a Malaysian manufacturer producing aluminum hard disk drive baseplates, a coated carbide endmill exhibited less abrasive wear and produced 95% more parts with 55% lower production costs than an uncoated tool.

The combination of coating hardness and a low friction coefficient can also dramatically improve production even when dry machining. In an application machining CFRP and thermoplastics, for instance, a Balinit Hard Carbon-coated countersink produced 180% more parts than an uncoated tool. In another case, a coated carbide endmill doubled the parts produced when dry machining compared with an uncoated tool using lubricant.

Diamond Coatings

When carbon content in composites or silicon content in aluminum alloys becomes too high, cutting tools typically require a diamond coating to minimize wear. Traditionally, PCD-coated cutting tools have been utilized in such instances. PCD is a composite of diamond particles sintered together with a metallic binder. Diamond is the hardest and therefore most abrasion-resistant material.

As a cutting tool material, PCD has good wear resistance but lacks chemical stability at high temperatures and dissolves easily in iron. So PCD tools are usually limited to materials like high-silicon aluminum, metal-matrix composites and CFRP. In addition, PCD tools are geometrically limited in structure and may be too rough or unrefined for optimal machining of the wide range of nonferrous materials. Finally, the initial cost of PCD cutting tools can be quite high.

As an alternative, plasma-assisted chemical vapor deposition （PCD） by Oerlikon Balzers is deposited on tools to machine nonferrous materials, including aluminum alloys with up to 12% silicon content.

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deposition can be used to apply crystalline diamond structures in varying thickness and roughness. This can be highly advantageous for machining CFRP, GFRP, graphite, nonferrous materials and ceramics. The diamond coating extends tool life while improving cutting quality and surface finish. With the PACVD process, a carbide cutting tool is sequentially coated by two different gases in a heated vacuum container assisted by plasma. The alternating cycles that built the atomic layer on the surface and the number of cycles thus control the thickness of the final coating.

“As a cost-effective, high-performance alternative, specialized PACVD-based diamond coatings can increase the service life of the tool,” Derflinger said.

He said standard PVD-applied metal-doped carbon coatings have a hardness of up to about 15 GPa whereas “diamondlike” carbon coatings range from 20 to 50 GPa. In comparison, a diamond coating reaches a hardness of 80 to 100 GPa.

The PACVD process allows the diamond coating to be applied at thicknesses from 6µm to 12µm, enabling customization to suit the application.

“Within any cutting process, the coating is constantly being removed,” Derflinger said. “The thicker the coating, the longer it takes to wear it off. Once you are into the carbide, the wear is accelerated further.

The ideal coating would have a very hard, protective surface that simultaneously maintains the sharp cutting edges.
So a thicker coating normally gives a longer tool life, which then lowers manufacturing costs.”

Balinit Diamond Micro and Nano coatings are examples of PACVD-based diamond coatings formulated specifically for the needs of a range of highly abrasive, non-ferrous materials. While both are well suited to machine GFRP, CFRP and ceramics, Micro’s formulation is ideal for graphite.

When it comes to machining aluminum alloys, including those with silicon concentrations of 17% or higher and ceramic particles, Nano’s diamond coating can replace more expensive PCD tools. For instance, in an application where a Duralcan composite workpiece composed of ceramic particle-reinforced aluminum materials was drilled, a PACVD diamond-coated cutting tool drilled 20 times more holes compared with even diamondlike carbon coatings.

The Nano coating also works well with abrasive CFRP and GFRP materials. In one example, approximately 380 holes were drilled with a PACVD diamond-coated tool when drilling workpieces made of CFRP and aluminum compared with about 60 holes with an uncoated tool.

Finally, when machining ceramics, which typically occurs in the dental industry, PACVD diamond coatings can substantially boost production and extend tool life while imparting fine surface finishes. As an example, when machining a zirconium-oxide workpiece for a dental application, a microscale PACVD diamond-coated ballnose endmill produced about 900 finished parts compared with about 100 parts for an uncoated tool.

The Bottom Line
Some manufacturers may be inclined to apply uncoated carbide cutting tools or tools with traditional coatings because of familiarity with such methods. However, those who take advantage of the superior capabilities of high-performance PVD and diamond PACVD coatings will improve part quality and lower production costs, improving the bottom line.

“Even if the cutting tool is expensive, you can put a hard coating on it and you will get a much better performance out of it,” Derflinger said. “That is why in the future more and more tools are going to have specialty coatings.”

For more information, contact Oerlikon Balzers at 248-409-5900, ext. 2121, or visit www.oerlikon.com/balzers/us.
When the quantity of cutting tools a company makes can achieve a return on investment in a few years, it makes economic sense to coat tools in-house. Superior Tool Service Inc. made that decision about a year ago and launched its STS Coatings division to coat not only the round tools STS produces but tools from other companies, as well as to decoratively coat a variety of products, such as firearms, said STS President Clint Whitney.

To perform physical vapor deposition coating, Wichita, Kansas-based STS reports that it invested $2.2 million in equipment and hired additional employees. STS has a German-made MpC1000 coating vessel from PD2i that has 12 spindles and can deposit a number of coatings, including TiN, TiCN, AlTiN, Alcron, AuRoRa, Micral TeToN and AlTiSiN.

“I spent a straight year studying and working with some coating shops and with the factory that makes the equipment,” Whitney said.

STS specializes in making custom tools and can coat different types and sizes of tools at one time. “We really have to tailor our recipes and fixturing to make sure we get the same coating thickness,” Whitney said.

Many applications require a tool that’s received multiple nanoscale layers of different coatings, he added. A chrome coating often is deposited first because of its high level of adhesion, with other layers providing a variety of properties, such as heat and wear resistance. The top layers must be hard and lubricious and have a high coefficient of friction. STS offers coatings as hard as 3,800 HV.

Prior to coating, tools go to the nonaqueous cleaning line, which uses a modified alcohol-based

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**about the author**

Alan Richter is editor of CTE. Contact him at 847-714-0175 or alanr@ctemedia.com.
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solvent, Whitney said. After being coated, the tools receive a post-processing treatment, such as drag finishing to enhance smoothness or aerolapping to impart a smoother, brighter finish. The latter is primarily for decorative applications.

Once a coated tool becomes too worn, it can be re-ground and re-coated two or more times, Whitney said. “There is a myth out there that some people think you can’t regrind coated tools because you’ll do more damage to your diamond wheel when grinding it. With titanium silicon, yeah, you get a little more wear on your diamond wheel but not enough to stop regrinding.”

Some people also have the misconception that a coating isn’t worth the additional expense, particularly when machining gummy materials. With a cobalt tool, for example, a coating proves effective when cutting such materials even without flood coolant, Whitney said. “If they’re running MQL, a misting application, a coated cobalt tool is going to outperform a noncoated tool.”

He estimates that a coating adds 1% to 5% to the tool cost while extending tool life 100% to 600% but concedes that the advantages of a coating might not be realized when running at a low spindle speed.

In addition to the significant investment in time and money to obtain a coating vessel and learn how to properly operate it, running a coating service requires a substantial amount of equipment maintenance, Whitney said. “Since you are coating everything inside of the vessel, you constantly have to keep up on that and clean.” STS operates the coating machine six days a week and spends one day on maintenance.

As STS Coatings continues to refine and promote its business, it continues to attract customers, Whitney noted. “We’re looking to grow twofold this year.”

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Abrasive waterjet machining can be a terrific complement to more traditional machining processes.

By Christopher Tate

Those employed in metalworking industries are probably familiar with abrasive waterjet technology. However, many likely do not understand its unique capabilities and benefits.

When we started Savannah (Georgia) Machinery Works in 2010, we had the opportunity to examine different manufacturing technologies and determined that waterjet cutting would be critical to the success of our startup. Almost every component in gas turbine
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Combustion hardware starts life as flat stock that is cut, formed and welded. Obviously, the flat stock has to be cut before we can do any forming and welding, so selecting the appropriate metalcutting machine tool was an important decision.

Most of our cut parts have non-rectilinear shapes, which require a CNC machine capable of producing complex shapes with different angles and radii. All current technologies, such as laser, oxy-fuel, plasma and waterjet cutting, have large tables, making them capable of holding entire sheets of flat stock.

Because programs were necessary to control the machine, we wanted to ensure that it was easy to program. Every cutting technology employs similar software that accepts various CAD files, making programming easy. In all cases, it was as simple as selecting the profile, telling the machine where to...
start, providing basic information about the workpiece material and pushing the start button.

Different Dimensions

The next consideration was material thickness. This is where we started to see distinct differences in capability between the thermal machines and the waterjet.

Our materials range in thickness from 1mm to 25mm, which presents a challenge when trying to select a style of machine. Thermal machines that worked well with sheets 1mm or 1.5mm thick, for example, using laser technology were not capable of cutting materials 15mm or 18mm thick. And the machines that could cut thick materials using plasma and oxy-fuel technology did not provide the specified cut quality. Waterjet was the only technology capable of delivering the desired profile definition over our range of material thicknesses. Waterjet technology, which uses high-velocity water mixed with garnet, can cut any thickness of material that fits under the head. An added advantage is that changeover from a thin to thick material is simple and done entirely through the control.

Combustion hardware operates in an extremely harsh environment and is subject to cracking and other mechanical failures, especially around welds. Almost all our

Pictured is the lower half of a gas turbine combustion component. The rectangular tabs and extra stock must be removed, which is done with a 5-axis abrasive waterjet machine at Mitsubishi Hitachi Power Systems Americas.
combustion parts require some type of welding operation after cutting. Because of these risks, our welds must be practically flawless and are subjected to rigorous inspection. Achieving the highest-quality welds requires the weld joint to be meticulously cleaned and prepared before striking an arc.

When compared with thermal methods, waterjet cutting is the cleanest way to cut parts. The cut edges are clean and well-defined and have no recast layer from the melting and solidification experienced with thermal cutting. Thermal methods force the welder to grind or sand the cut edge to ensure that oxidized material—the recast layer—does not contaminate the weld. No melting takes place with waterjet machining, so there is no oxidized surface to clean.

Under Pressure Waterjet machines pressurize water to very high pressures, with 60,000 psi being common. Some machines are capable of even higher pressures. The pressurized water is presented to a small-diameter orifice, and the restricted flow combined with the pressure create a jet that can travel four times the speed of sound.

Ironically, the workpiece does not experience high cutting forces in this environment. This is a considerable advantage at my company because we have parts with complex shapes, and securely holding them with traditional machine tools would necessitate expensive, complex fixtures. Waterjet cutting allows us to employ simple, inexpensive workholding. In fact, we would have had to resort to a much more complex manufacturing process without waterjet technology.

The technology is surprisingly accurate compared with most
thermal processes. When properly maintained and correctly set, a waterjet machine can routinely hold a tolerance of ±0.1mm. Some manufacturers claim to hold ±0.025mm. My company regularly holds to ±0.1mm on small-diameter holes in 5mm- and 6mm-thick materials. I suspect we could do better if necessary, but it would require significant development time.

Waterjet cutting allows a user to cut what seems to be an unlimited array of materials, including cardboard, plastic, wood, foam and ceramics. Simply tell the control what material is being cut, along with the thickness, and the control will compensate. Waterjet machining does not produce fumes, gases, dust or other airborne contaminants, and there is little chance of starting fires, unlike with thermal processes.

For us, waterjet technology was the right choice and has proven to be the perfect complement to the more traditional manufacturing processes we use. We did not realize how important our waterjet machines would become when they were purchased. Over time, they began to play a role in some of our most meaningful manufacturing processes and allowed us to make parts we may not have been able to produce otherwise.

These parts have been through the waterjet machine and are ready for laser welding. Because waterjet cutting does not create a recast layer, no grinding or sanding is needed to remove one.

C. Tate
Anthony Machine Inc. previously focused on producing medium-size parts in quantities from 10 to about 100, said Eugene Ponomarev, the machine shop’s general manager and vice president. Wanting also to serve the market for small parts, the San Antonio shop purchased its first Y-axis, live-tool lathe, a DMG Mori NLX 3000 1250 turning center. After succeeding with that machine, the business bought a second one, he added.

With a priority to accomplish short lead times while offering competitive prices, Anthony Machine’s manufacturing team was challenged to make the most of the new investment. The manufacturer turned to Mark Davis, senior sales engineer for Latrobe, Pennsylvania-based Kennametal Inc., who has worked with Anthony Machine for about a decade. The shop already had experience with Kennametal’s KM quick-change toolholders.

“Over the years, we’ve built a number of KM-equipped custom toolholders for deep boring and..."
Mohsen Saleh (left) and CNC Machinist Setter Mark Garland discuss a workpiece produced on one of Anthony Machine’s DMG Mori NLX series universal turning centers.

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other machining operations on our CNC lathes and machining centers, and we use Kennametal on several of the shop’s manual turret lathes to overcome limitations with available tool positions,” said Manufacturing Technologist Daniel Goller. “On more than one occasion, we’ve earned new business because KM was able to achieve tolerances and surface finishes that others couldn’t do with conventional tooling.”

The shop has about 20 pieces of CNC equipment, including vertical and horizontal lathes and vertical and horizontal milling machines, and employs about 25 CNC machinists, he noted. In addition to KM toolholders, Davis explained that the best way to reduce setup times and maximize the new machines’ potential would be to equip them with turret-adapted clamping units.

“He made us aware of the new units,” Goller said. “Knowing the KM connection previously, he knew it was what we wanted to do.”

“The TACU system supports everything from KM32 up to KM63,” Davis said. “We offer blocks for both static and driven tools and can tool up lathes from Okuma, Haas, Mazak, Doosan and of course DMG Mori—pretty much all of the major machine tool builders, with more coming online all the time. This makes it both easy and cost-effective for our customers to equip more than 80

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Mohsen Saleh, operations manager for Anthony Machine, agreed.

“Compared to the traditional wedge and screw-style blocks that come standard on most machines, the KM-equipped TACUs are both faster and more accurate,” he said. “We routinely hold tolerances of 0.0005”, and I’m told that part size doesn’t change from one clamping to the next. The turret is less crowded, everything is easier to get at, and you don’t have the chatter and deflection that you often find with your typical straight-shank tools and set-screw-type boring bar holders.”

Goller added that the traditional block connection was cumbersome because it required a machinist to hold several different parts, mount the part and make sure everything was straight. The KM toolholders, on the other hand, have a taper and face connection that mounts with a couple of turns of a torque wrench.

“The KM connections just repeat and are always straight,” Goller said. “You don’t have to fight to make sure your tools are right. There is only one way to put them in. There is no misalignment like there might be with conventional tooling.”

For example, if a boring bar is not aligned properly, it affects cutting geometry, which means that a machinist is more likely to have issues with chatter, Goller said.

“On the other machines, we are happy if we hit a 32 µin. Rₐ finish, which is not much to write home about,” he said. “On the new machines, we easily hit 10 to 11 µin. Rₐ.”

With the KM-equipped TACU system in place, Goller said Anthony Machine reduced tool setup time by about 50%.

“After seeing the benefits of using KM on Anthony Machine’s new NLX machines, the company plans to expand its use of quick-change tooling to other areas of the shop.”
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EXTENDING TOOL LIFETIMES

By Robert Weinstein

Manufacturers always seek ways to extend the lifetimes of their cutting tools while boosting productivity. A team of researchers at Linköping University (LiU) in Sweden is helping to do just that.

The team has focused on how tools degrade, specifically examining the materials used to coat metalcutting tools to make them harder. In particular, the team has researched TiAlN, a ceramic material widely deposited as a coating.

On one hand, the material is effective for coating because it becomes harder while in use. This age-hardening process works well up to about 700° C. However, degradation starts to occur when the temperature reaches 900° C, which can happen after a few minutes of cutting into an especially hard material.

“It’s one thing to know that the material degrades at those higher temperatures,” said Kostas Sarakinos, head of LiU’s Nanoscale Engineering Division. “It’s another thing to know why and the way by which it degrades during cutting. To fully understand that, we need to get down to the alloy’s atomic level.”

He and his colleagues have spent four years developing a theoretical model to explain the degradation, examining over three dozen structures and configurations of TiAlN to determine how the atoms interact in different conditions, including the high temperatures and pressures that prevail during machining.

Working with LiU’s supercomputer to process the enormous calculations involved, the researchers have been able to calculate numerous reference properties of the alloy structures, such as elastic responses and melting temperatures. These properties were then benchmarked against actual behaviors of the material. This success gave researchers confidence that their model can be used to perform reliable simulations at time and length scales in a way that has not been possible thus far and thereby project the TiAIN alloy’s physical behavior down to the atomic level.

“We can now examine changes at the atomic structure of the alloy by the picosecond,” Sarakinos said. He said this level of detail will provide insight into thermally activated mechanisms, including the well-known spinodal decomposition, that affect the structure and stability of the alloy. This understanding will drive development of knowledge-based design rules toward a new generation of high-performance ceramic coatings.

While moving forward with the theoretical studies, the researchers hope that their results produce practical applications for manufacturers. For example, there are collaboration agreements between LiU’s researchers and Sweden-based toolmakers Sandvik AB and Seco Tools AB.

Ultimately, as the theoretical and applied research come together, the objective is to extend the life spans of tools while giving greater resilience to them. Such results would also lower manufacturing costs. The long-term goal is to not only delay degradation of coating materials but avoid it altogether.

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For more information about Linköping University, call +46-13-28 10 00 or visit www.liu.se.

Robert Weinstein

Robert Weinstein is a contributing writer for CTE. Contact him at 732-583-7171 or gersonpub@aol.com.
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