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2. Your job title (check one):
   1. [ ] Corporate Manager
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      (Non-Supervisory Position);
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   7. [ ] Purchasing;
   8. [ ] Quality Assurance, Control;
   9. [ ] Other (please specify)

3a. What is the primary end product manufactured (or service performed) at this location?
   331 [ ] Primary Metal Manufacturing
   332 [ ] Fabricated Metal Product Manufacturing
   333 [ ] Machinery Manufacturing
   334 [ ] Computer/Electronic Product Manufacturing
   335 [ ] Electrical Equip/Appliance & Component Manufacturing
   336 [ ] Transportation Equipment Manufacturing
   337 [ ] Furniture and Related Product Manufacturing
   339 [ ] Miscellaneous Manufacturing
   423 [ ] Wholesale/Trade/Durable Goods
   999 [ ] Other Manufacturing NEC

3b. If your company does NOT manufacture AT THIS LOCATION, specify company’s primary product or service performed. (please specify)

4. Number of employees at your company.
   A [ ] 1-9       C [ ] 20-49       E [ ] 100-249       G [ ] 500+
   B [ ] 10-19     D [ ] 50-99       F [ ] 250-499

5. Which of the following market segment(s) does your company serve? (check all that apply)
   1. [ ] Aerospace
   2. [ ] Communications, Computers, Electronics
   3. [ ] Defense
   4. [ ] Energy
   5. [ ] Heavy Equipment
   6. [ ] Medical
   7. [ ] Transportation (including automotive)
   8. [ ] Other (please specify)
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Why buy an add-on rotary table over one built in to your machining center?

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Hurco Cos. Inc. partners with educational institutions to train CNC machinists. Tour Oakland Community College’s facility to see why manufacturing curricula choose Hurco.

CTE Owner/Publisher Dennis Spaeth walked the aisles at Eastec 2019 with his trusty camera in hand. Take a look at some of the highlights.

Superior Tool Service Inc. decided to coat tools in-house, launching its STS Coatings division to coat its round tools and tools from other companies.

Three Ed Carpenter Racing cars carried the Hurco Cos. Inc. logo across the finish line at the Indianapolis 500. Hurco CNC machines produce parts for the ECR motorsports team, which finished with cars placing sixth, 13th and 14th in the 500-mile Memorial Day weekend classic. See this and more on CTE social media.
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An innovation to a cutting tool can be significant, but transforming a machining process can have an even more profound impact. During the Ceratizit Open Days 2019 press event, the Mamer, Luxembourg-headquartered cutting tool manufacturer unveiled its High Dynamic Turning (HDT) with FreeTurn tools, and Dr. Uwe Schleinkofer called it an innovative change to a process that basically has remained unchanged. He is head of R&D cutting tools for Ceratizit Austria GmbH and made his comments at the Ceratizit Reutte facility in Breitenwang, Austria.

In addition to the Austrian plant, the event included tours of three of the toolmaker’s German facilities in Stuttgart, Balzheim and Kempten. Check out my photo-heavy blog post about the trip at tinyurl.com/yrpo4yn.

To develop the turning technology and the tools, Ceratizit partnered with machine tool builders, control manufacturers and CAD/CAM software developers. According to the company, the idea behind HDT is simple: The tool’s approach, or lead, angle and point of contact in the machine can be varied as opposed to conventional turning in which a contour is created with an indexable insert at a fixed angle to the workpiece. Therefore, conventional turning requires a separate insert for each contour that needs to be produced.

The FreeTurn inserts have roughing and finishing edges, but one edge can be applied for both, depending on the application. One tool, however, performs all traditional turning operations, such as contour, face and longitudinal turning.

The machine tool must have X, Y and Z linear axes and B and C rotation axes. The multitask machine’s milling spindle functions as the toolholder, and the milling spindle must have an HSK-T or Capto-compatible PSC tool connection and cutting edge compensation in the Y-level.

Early stage programming of the tool is possible with various software packages, such as Siemens Sinumerik 840D, Mazatrol and FANUC. However, that approach enables a user to achieve only the “light” version of HDT because it takes a high level of skill to program a machine with G code. Achieving “full” HDT requires development of new CAD/CAM software to overcome that obstacle and enhance market penetration, and Schleinkofer tentatively expects a developer to introduce the needed software in September at the EMO Hannover trade show in Germany. HDT with FreeTurn tools will be available in the U.S. after the show.

During a couple of presentations, Ceratizit did acknowledge two recent turning developments: Vandurit’s rollFeed (vandurat.de/en/rollfeed) and Sandvik Coromant’s PrimeTurning (sandvik.coromant.com/en-gb/campaigns/primeturning). Nonetheless, Ceratizit said HDT distinguishes itself from those technologies and is “a completely uncompromising method of turning.” As always, the marketplace will have the final say.

**about the author**

Alan Richter is editor of CTE. Contact him at 847-714-0175 or alanr@ctemedia.com.
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MACHINING CENTER FOR AEROSPACE COMPONENTS: Chiron Group SE has introduced the FZ 16 S 5-axis machining center with a 5-axis tilt rotary table. High-performance motors, two Y-axis drives and short spindle starting and braking times enhance the machine’s speed. The machine has a mineral cast bed and rigid gantry design. It is suitable for producing complex aerospace components, such as vanes, blisks and impellers.

Chiron Group SE; www.chironamerica.us

DRAG FINISHER IS FOR CARBIDE, HSS TOOLS: Bel Air Finishing Supply Inc.’s AutoHone reverse drag/stream finisher requires virtually no operator involvement. A 6-axis robotic arm enables control over part articulation, an important factor when honing cutting tool edges and polishing flutes. The finisher is modular and customizable with an optional ultrasonic cleaner and blow-dry station.

Bel Air Finishing Supply Inc.; www.belairfinishing.com
COOLANT FILTRATION SYSTEM FOR CNC MACHINES: MP Systems Inc. has introduced the Purge coolant filtration system to prevent chips from accumulating inside a CNC machine’s coolant tank and causing coolant starvation of the machine tool’s flood and high-pressure coolant pumps. The full-flow system pulls coolant from the dirty side of the coolant tank, filters it and returns coolant to the clean side of the tank faster than the coolant pumps draw from it.
MP Systems Inc.; www.mp-systems.net

ENDMILL IS FOR CUTTING NICKEL-BASE MATERIALS: To effectively machine Inconel and other nickel-base superalloys, LMT Onsrud LP offers the MXR series endmills. The tools allow for 15% radial engagement during machining. The 4- or 5-flute tools are available with multiple corner radii, including a 4-flute ballnose cutter for contouring. The endmills are coated with the company’s EnduraSpeed and edge-conditioned to increase tool life and performance.
LMT Onsrud LP; www.onsrud.com

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Hoffmann Group USA; www.hoffmanngroupusa.com

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Dillon Manufacturing Inc.; www.dillonmfg.com

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What goes around comes around, including good things. Representing your company through community involvement accomplishes multiple goals. Something hopefully has been made better. In return, your and your company’s reputations possibly have been raised, even to the point of gaining access to a network of valuable contacts and prospects.

The term “community involvement” sounds great but is not always possible to perform. If you wanted, you could find an event every day. But your volunteer time is limited. You can’t say yes to everything. That’s understandable, especially for owners and managers of small machine shops. However, if you can and are willing to give your time, benefits to your business are likely to follow.

One can become involved in a lot of ways, many of which are industry-related and contribute to the success of a company. A few years ago, I participated in a job fair at a school at the request of a friend. I discussed manufacturing careers, machining and related subjects with students. I’ve also assisted our local community college system by participating in curriculum development panels. My participation

**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.
allowed me to meet prospective customers, eventually getting business from a fellow participant. Soon after that, a friend informed me of another such panel the college was assembling for a machining program and asked if I’d be willing to contribute. The problem was, it was a four-hour commitment in the middle of the week, and my free time was limited. My initial thought was, “It’s someone else’s turn, and I’m too busy.” Then, I noticed the many names and email addresses of the other invited panelists and discovered they were largely a who’s who of potential customers and interesting colleagues. Upon further consideration, I realized that it was a good time to get involved again. I would help with a worthy project and at the same time get something in return through new relationships with key people.

Your company might be noticed for its positive involvement, and you may share a table or conversation with an important person or a new prospect. Maybe you will meet a newly needed supplier or a college professor who will direct skilled job candidates your way after successful completion of training programs, all at no cost to your company. If people ask for your input, you might as well give it to them. Your involvement will be respected and appreciated. The bottom line is that a few hours of effort can open doors.

Many similar examples could help your industry, community and company. Maybe sponsor a team, host a fundraiser, allow employees to volunteer for a worthy cause or donate parts or engineering time to an organization, as my company did with a high school robotics team. You can’t say yes to every request, but the knowledge, expertise and desire for goodness shared among you and your team are very valuable. Harness those passions, and make a name for your company.

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A miniaturized system for spindle monitoring could have a big impact on machining costs.

Developed by Balance Systems SRL, Pessano con Bornago, Italy, the B-Safe System contains a sensor unit with a cable, along with an electronic interface. The sensor unit attaches to a machine spindle, and the cable transmits data from the unit to the electronic interface, which is stationed in a nearby electrical cabinet.

Measuring ½” in diameter and 1¼” in length, the sensor unit’s housing is the smallest of its kind in the industry, said Francesco D’Alessandro, manager of Balance Systems’ branch in Wixom, Michigan. In addition to sensors, the unit contains a microprocessor with integrated memory.

“It’s not a simple sensor but a real microcomputer,” he said.

Sensitive elements in the unit include a temperature sensor and a 3-axis accelerometer that detects spindle vibration and the direction of spindle movement. The sensors use a combination of 3D microelectromechanical systems and piezoelectric technology to analyze signals. The sensor unit must be firmly attached to the spindle to accurately detect vibration and temperature. For this purpose, Balance Systems provides a magnet and various mechanical adapters.

B-Safe’s electronic interface includes a bus converter that changes the signal from the sensor unit so it can be read by a PC and
transmitted via the internet. The interface also houses a small battery that provides power to the sensor unit to enable spindle monitoring even when machine power is off.

One of B-Safe’s main functions is to detect any type of collision during machining—for example, a tool colliding with a workpiece or machine component. The system identifies collisions by detecting spikes of vibration and temperature that reach or surpass preset thresholds. When this occurs, B-Safe stops the machine within 1 millisecond to prevent expensive damage to both the machine tool and workpieces. B-Safe halts a machine by sending a signal to the inverter or programmable logic controller. When a collision is detected, B-Safe also provides users with spindle vibration and temperature data for the time period from four seconds before the collision to one second afterward.

“If you want to do some post-process analysis of your collision,” D’Alessandro said, “you can see exactly what was happening in your spindle during the four seconds...
B-Safe features a predictive maintenance function that estimates the remaining lifetime of a spindle based on the use of a machine tool. During machining, the system uses collected vibration and temperature data to determine the severity of the conditions in which the spindle operates. The system then adjusts the spindle lifetime accordingly. The results are shown using a bar that changes in length and color as time passes. Predictions of remaining spindle life help users schedule maintenance periods for times when they are least disruptive.

“Suppose you are close to your Christmas shutdown, and your spindle (has reached) 80% of its life,” D’Alessandro said. “With that information, you might decide to rebuild the spindle over the Christmas shutdown. You’ll lose the 20% of residual spindle life but with the benefit of not having to stop the machine to rebuild
the spindle during working time.”
One possible downside of the system is that it does not transfer data wirelessly between its two components. While wireless sensors are commercially available, he pointed out that regulations require B-Safe components to be connected via cable because the system’s damage-minimizing collision detection capability is considered a safety feature.
“So when you install it, you have to figure out how to run the cable between the spindle and the electrical cabinet,” he said.
Potential users, however, may well decide that’s an acceptable price to pay for a safer machining process.

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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.
The following tips and unusual methods of machining have worked for me and may assist you.

■ When I saw some flimsy Delrin parts being run, I hoped I wouldn’t have to get involved. The programmer chose to apply large endmills to machine the parts. Initially, the job was not going well. Parts were being pulled from the vise jaws, and chunks of Delrin were flying. So I asked to get involved. I reprogrammed the parts to be made with smaller-diameter endmills, which cut with less pressure. I also chose to use single-flute cutters with a 0° rake angle when necessary to avoid the lifting forces inherent with positive rake endmills.

■ When verifying a program,
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set center drills to spot only. Let’s face it: We’re only human, and sometimes we screw up. When drilling a part, especially one that already has a lot of time invested in it, care must be taken that holes and other part features end up in their correct locations. One way to verify the setup when drilling is to set the center drill to just lightly spot the surface. If the locations happen to be off for some reason, you’ll have a chance to correct the error.

- Manually set countersink depths at the machine. Countersinking tools run the gamut in terms of how they are made. They vary in numerous ways, such as angle, tool tip size and number of flutes. These variations make it difficult for a programmer sitting at a computer to set a precise depth. Because machinists generally set a precise depth for a countersink tool, a programmer likely won’t know which countersink tool will be used. Instead, I program the tool tip to stay a little above the part and let the machinist manually find the correct Z negative value, which then can be entered into the canned cycle that runs the tool.

The easiest way I’ve found to do this is to run the program until the countersink tool is called up. Then, stop the program by hitting the reset button. After that, start the spindle with the clockwise, or CW, button, and slowly handle-jog the tool to the proper depth in the part. Take note of the

about the author

depth using the operator’s digital readout. Enter that value in the canned cycle that runs the tool. The only catch is that the operator’s screen must be zeroed in to Z beforehand to the tip of the countersink tool, or the value shown on the screen won’t make sense. Dimensions for countersunk holes are generally not too critical. These dimensions are used mostly for flat-head screws and lead-ins for tapped holes.

**Sometimes, you must leave a machine’s doors or windows open to accommodate a part or feature of a part. Make a mental note to be extra-cautious when doing this.**

- Be especially careful when running large parts with the machine’s doors or windows open. Occasionally, you’ll run into capacity issues with machines. These issues often can be overcome with thoughtful planning. Sometimes, you must leave a machine’s doors or windows open to accommodate a part or feature of a part. Make a mental note to be extra-cautious when doing this. It’s a recipe for crashing because your travel may be limited to the openings of the doors or windows, not the total travel of the machine table. I once saw a nasty crash when a machinist clamped a long plate to a machine table with one end of the plate hanging outside the doors. For whatever reason, the machinist homed the machine. In rapid mode, the table went home but not before leaving a big gash in a door as a result of the edge of the plate slamming into it.
As readers of this column know, I’ve worked for several manufacturers over my career: some good, some not so good. One thing that they have had in common, though, is they all provided benefits in some form.

Early in my career, I worked at a company in Chicago for a few years that paid well and had great benefits for that time. We had something like 12 paid holidays, terrific company-paid health insurance—but no dental or vision coverage—and a pension plan paid 100% by the company. Those were the benefits for regular laborers at the plant. Eventually, I reached salary status at the company when I became the machine programmer. In addition to the benefits listed, I received what was similar to a modern 401(k) program. I could contribute up to 7% of my salary, and my contribution was matched 100%. In retrospect, I was an idiot at the time to leave. Ah, the young and the restless.

I left that company to work as an applications engineer for a machine tool builder. I took the job assuming I would be paid biweekly like my previous job. Not! I wasn’t paid weekly either. Monthly! I had to not only stretch my paycheck but adjust to the government taking a bigger percentage due to the size of the checks. Sure, I got a refund at tax time, but I needed money when I was paid. I stuck it out for a couple of years there and then moved on. During those years, people changed jobs for even a quarter more an hour and didn’t think twice about it.

Then, I worked on contract for several years. I got decent pay but no benefits to speak of. If I took off a day, I didn’t get paid. If I wanted...
insurance, some companies didn't offer any. The ones that did provide insurance charged what seemed a prohibitive price. Typically, there was no pension or 401(k) and no paid holidays. I did get paid 1.5 times my normal pay rate for overtime.

One contract house out East did pay for my holidays. After one year, the company even gave vacation pay. It wasn't much, but a week was a week. Insurance remained pricey, and there still was no pension. I could contribute to a 401(k), but there was no match.

Another company I worked for in the East paid well. It had a good health plan and a 401(k). There was still no dental or vision, though. I got nine paid holidays plus three sick days. The bonus plan was really nice. It was on a bimonthly schedule and usually in the range of $750 to $800. After the business was acquired, the bonuses became smaller and semiannual.

There were good benefits at another company I worked at for several years. It provided a few paid holidays, sick days and personal days, along with two weeks of vacation in the first year and three weeks of vacation after five years. A 401(k) was matched up to 6%. An annual bonus also was paid. Last but not least were the company luncheons and breakfasts.

The company I work for now isn't too shabby with benefits. It is as good as or better than any of my previous employers. I don't have anything to compare outside the companies where I've worked. How does your company fare? I'd be interested to find out.
Of all machining processes, wire EDMing is perhaps best suited for lights-out manufacturing. No chips get in the way. There are no worries about cutting tool wear or breakage. And if a wire breaks or shorts out, the machine tries to rectify the problem before notifying a human that it needs help. This allows tool and die makers and an increasing number of traditional machine shops—especially those serving the aerospace and medical industries, where wire EDMing is used to cut otherwise unmachinable part features—to significantly boost available machine time while reducing labor costs.

Tap, Tap

Unfortunately, the one thing that can go wrong might actually break the machine tool. When a slug comes loose, it can fall into the lower nozzle and cause damage or become jammed between the head and workpiece. One inelegant solution is so-called slugless EDMing, in which the wire vaporizes the slug, but this eats up huge amounts of time, wire and electricity. Small metal tabs can be left to support the slug until the next morning, but removing them requires additional processing and human intervention.

Steve Raucci, EDM product manager at Methods Machine Tools Inc., Sudbury, Massachusetts, offers a solution. He said the Core Stitch function on FANUC RoboCut α-CIB series wire EDMs retains slugs in the workpiece via a reverse discharge “brass adhesion” process, leaving small islands of soft material that hold slugs in place. After roughing, a few light taps with a plastic or
GF Machining Solutions' ASM system uses compressed air to lift and remove just over a ½-lb. slug, which then is deposited into a basket at the side of the machine.
brass hammer are enough to separate a slug, whereupon the operator can return the workpiece to the wire EDM for final machining if necessary.

A hammer helps achieve lights-out machining because, for starters, Core Stitch eliminates the need to stop a machine and apply electrically conductive glue or magnets to hold slugs, automating what was once a manual function. As Raucci explained, the tapping function itself also can be automated.

“We have an aerospace customer that’s using a FANUC robot as part of a machining cell,” he said. “The robot removes a jet engine component from the EDM and sets it on a slug removal station. It then exchanges its grippers for a brass punch, knocks out the slugs and places the part back into the machine for a final skim pass.”

**Slugging It Out**

GF Machining Solutions LLC, Lincolnshire, Illinois, takes a different approach to wire EDM slug management. EDM Product Manager Eric Ostini said the company’s AgieCharmilles Cut P series wire EDMs can be equipped with an automated slug management mechanism that uses a Venturi-style vacuum to basically suck slugs out of a workpiece.

“As the slug breaks free, it’s supported by the lower head while the upper head lifts up and out of the way, allowing the attached ASM mechanism to move into position,” he said. “The ASM uses compressed air to generate enough suction to lift and remove just over a ½-lb. slug, which is then deposited into a basket at the side of the machine. The upper head then returns to its previous position and either finishes the cavity or moves on to the next one, all completely lights out.”

An unattended machining strategy, however, requires more than...
automated slug removal. Flawless automatic wire threading is also needed. FANUC America Corp., Rochester Hills, Michigan, addresses this with its revamped AWF3 automatic wire feed system. Raucci said the new threader includes an integrated air supply that runs the length of the annealing tube, allowing the machine to thread while fully submerged, even at the maximum 20” Z-height.

“It’s very accurate,” he said. “We can thread a 0.01” wire, for example, through a 0.015”-dia. hole and are able to feed the wire through much taller kerfs than the previous generation. Couple that with the machine’s automated probing, coordinate rotation, remote management features and extreme reliability, and it means you can load it up with a 66-lb. spool and come back 100 hours later to a pile of finished parts.”

Trust, but Verify
Because robust threading is important, Ostini said GF Machining Solutions created its Threading-Expert and automatic wire changer systems. But just as important is knowledge of wire breaks and other process-related events. That is why the company has developed eTracking software that constantly monitors and records the spark condition related to specified norms, generator parameters and

contributorss
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“It also provides an area where step-by-step work instructions are presented to the machine operator, which will not allow the machine to start unless the operator verifies that each step was performed,” he said.

Makino Inc., Mason, Ohio, is another wire EDM builder that recognizes the need for efficient, predictable lights-out machining. Brian Pfluger, EDM product line manager, noted that his equipment easily checks the dependable threading box thanks to a jetless threading system, which is reportedly able to thread through 4” of kerf with 100% reliability. He also said smaller slugs are manageable with Makino’s dual-pump, independently programmable flushing system. Yet he’s quick to point out that shops must have several
other critical functions in place before turning out the lights.

To achieve no-fail remote monitoring and data collection, wire EDMs should have hard-wired network connections, not wireless. Pfluger said this will avoid the “electronic hell” created by EDM spark generators. Highly accurate, repeatable, automation-ready workholding also is needed. But it’s the accuracy of the machine tool that he said is the main ingredient for predictable unattended EDMing.

“An increasing number of shops are asking us about automation, but my response is that a high-quality, highly accurate machine tool must be in place first,” he said. “This means a machine with the requisite mass and thermal stability for round-the-clock operations. It should have positioning and feedback systems suitable for the parts being produced. And just as important are consistent, reliable processes. Automating inefficient or unpredictable ones will lead to poor results.”

**More Accurate, No Recast**

One example of this is Makino’s UP6 Heat. Though designed with progressive stamping die manufacturers in mind, the wire EDM’s


1μm precision across its entire 25.6”×18.5” working area should be of interest to anyone producing extremely accurate parts in an unattended fashion.

Makino also offers the Hyper-Drive system, which helps improve straightness and accuracy, particularly in small part details, Pfluger said.

The good news for shops looking to automate wire EDMing is that a wide range of high-quality machine tools and options are available, all of which make the leap to lights out much easier. Evan Syverson, additive business development manager at Sodick Inc., Schaumburg, Illinois, said EDM technology has made significant strides in recent years, making it a viable machining process for manufacturers that once worried about EDM-generated recast layers and suboptimal surface quality.

He pointed to increased use of electrolysis-free power supplies together with glass scale feedback, linear motors, ceramic components and servo-controlled wire tensioning as the key drivers behind these improvements. The developments make wire EDMs, such as Sodick’s ALN series, more accurate and better able to impart extremely fine surface finishes.

On the automation side, Sodick’s Super Jet AWT high-speed threading and wire tip disposal units...
reduce operator intervention.

“The tables have definitely turned with wire EDM,” Syverson said. “It’s become far more mainstream, and shops are looking for ways to automate it, just as they are for their other machine tools.”

Mike Bystrek, EDM applications and national wire EDM product manager at MC Machinery Systems Inc., Elk Grove Village, Illinois, agreed, saying the company’s MV2400-ST Advance Type wire EDM is an excellent example of state-of-the-art EDM technology.

“The new M800 control platform enables us to offer a pedestal option, providing easy mobility and access to any position near the machine for flexibility in automation layouts or safety purposes,” he said. “It also offers enhanced setup and maintenance functions that greatly reduce downtime, as well as remote management features for unattended machining.”

One of these new control features is a built-in scheduler.

“The scheduler allows the operator to easily change the order of operations of the workpieces while machining,” Bystrek said. “This type of flexibility is crucial when maximizing your attended operation.”

Like Pfluger, Bystrek suggested that shops would do well to look

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beyond the wealth of available machine tool and control features and focus instead on internal processes and the capabilities needed to support them.

“It’s also important to have a very good team, a team that includes at least one—and preferably more than one—EDM expert on staff,” he said. “A lot of companies don’t have this, especially those without a long history of EDM use. In lieu of this, shops should look for a machine tool partner that’s able to support them with knowledge and advice that will help them develop sound machining processes and the equipment needed to execute those processes. Without that, the only thing automation is going to do for you is make bad parts more efficiently.”
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Effectively machining titanium alloys requires suitable cutting tools, machine tools and monitoring systems.

By Alan Richter

Applications for machining titanium alloys are on the rise, especially in the aerospace industry. This growth results from more carbon fiber-reinforced polymer being put into aircraft for weight reduction purposes, according to Scott Walker, chairman of Mitsui Seiki (U.S.A.) Inc., Franklin Lakes, New Jersey. He explained that the composite material increases a plane’s susceptibility to electrolysis erosion when introduced into structures that traditionally incorporated a significant amount of aluminum. “A battery is basically carbon fiber, aluminum and water. That is why titanium has migrated. When you had all aluminum, you did not have that issue.”

Most titanium machining applications involve Ti6Al4V (6% aluminum and 4% vanadium) while others typically need Ti-5553 (5% aluminum, 5% molybdenum, 5% vanadium and 3% chromium) and 10-2-3 titanium (10% vanadium, 2% iron and 3% aluminum).

“A lot of aircraft guys have tried to steer away from 5553 and 10-2-3 because of the difficulty and cost of machining it,” Walker said. “However, those materials are still required on the high-stress areas on the aircraft, like engine...
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mounts, side body cords and landing gear components.”

To help jet engines run hotter and lighter than current designs, titanium producers are developing and testing new grades that might be even more challenging and costly to cut, he noted.

In the Cut

Effectively machining titanium, an element with the atomic number 22, begins by having the proper cutting tools. One toolmaker with offerings targeted at titanium is Allied Machine & Engineering Corp., Dover, Ohio. Other than Allied’s 4TEX indexable carbide drill, the best option for drilling titanium, according to Field Sales Engineer Nate Craine, is Allied’s APX drill with a special replaceable insert.

Although some end users consider titanium a heat-resistant superalloy, that’s not the case. “A lot of people like to lump titanium into the same category as high-temp alloys, but it’s its own breed of material that needs to be treated differently,” Craine said.

He emphasized it’s critical to understand that friction and inadequate chip evacuation cause titanium to workharden while being drilled. As a result, a titanium workpiece with a hardness of 32 HRC might workharden to 50 HRC inside the hole, which makes every process that follows drilling more complicated. “You could potentially destroy a boring tool,” Craine said.

One way to help avoid that problem is by selecting a tool with the proper relief angle so it doesn’t rub the workpiece material. “In titanium, you have the propensity for the material to pinch the side of the drill, so we developed a geometry designed for greater success,” Craine said.

Although that application-specific design requires the drill to run at a lighter feed rate, most titanium aerospace applications, for example, don’t have a need for speed, Craine added. “The material costs are more of a concern. If you can get that job done without damaging the part, then that’s a success.”

In addition to the relief angle, a drill must have the correct rake angle and hone to effectively cut titanium, noted Kevin Vanderbeck, East Coast field engineer for Allied Machine.
During tool life testing at a customer’s facility, this 2.5”-dia. drill produced six holes per T-A insert for a total length of 90” and two to three holes/edge with a –PWHR insert or four to six holes/edge with a –PW insert when drilling Timetal 17 (Ti5Al2Sn4Mo2Zr4Cr) with a hardness of 34 HRC at a cutting speed of 82 sfm and a feed rate of 0.0035 ipr. The high-strength, deep-hardenable forging alloy is primarily used for jet engines. According to Allied Machine, chip formation was much better when drilling at 131 sfm and 0.0055 ipr, but tool life can drop if the machining parameters are excessive.

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However, producing a cutting edge with the correct hone is a balancing act, according to Craine. Too much of a hone and the tool performs like it is dull, while an edge that is too sharp is prone to chipping.

To further enhance its T-A drills, Vanderbeck said Allied Machine performs a proprietary process “affectionately called the ultragrind” to create the ideal cutting edge for increased tool life and chip control. “That process minimizes fracture points along the cutting edge,” he added.

Without proper chip formation, titanium chips can become like ribbons and hard to evacuate. “If you are drilling anything more than three times diameter, that long ribbon will bind up and seize your tool,” Vanderbeck said. “It goes bad real quick, and a lot of times you don’t have time to hit that e-stop. By the time you see it, it is too late.”

Keep It Cool

Tool coatings and coolant play important roles when combating the high level of heat generated from cutting titanium. For coatings, Vanderbeck recommends...
TiAlN or Allied Machine’s proprietary AM200 or AM300. The advantage of AM200, he noted, is that the coating achieves the same level of lubricity to overcome built-up edge as TiAlN but at a lower temperature.

Craine added that Allied Machine offers polished inserts with AM300 coating to minimize the chance of titanium sticking to the coating.

But without an ample supply of coolant, even the most heat-resistant coating will struggle. “The more coolant you can get, the better,” Craine said, adding that it must be a water-soluble solution instead of oil because titanium is flammable. For that same reason he also recommends that the coolant be delivered through the tool. “I’ve drilled a one-times-diameter hole with flood coolant, but that is as deep as I would go in most circumstances.”

Although one East Coast manufacturer running straight oil as coolant didn’t have problems with flammability, the company definitely wasn’t achieving optimum results. Oil is necessary for lubricity and reduction in friction, but water is also important as it pulls remaining heat away from the cutting zone.”

Once Vanderbeck’s New England-based customer switched to a water-soluble coolant, it achieved longer tool life than when the company originally had started using straight oil, he added. “Tool life is much longer and more stable, and their chiller isn’t working as hard as it once was when they used oil and struggled to manage the dissipation of the heat.”
Vanderbeck pointed out it’s essential to maintain coolant at the correct concentration, which is a bit higher for titanium applications. “I strongly recommend that manufacturers consult their coolant supplier for the best coolant concentration for their titanium applications.”

A Changing Strategy
As cutting tool manufacturers design cutters that have significantly more positive rake angles, not as much cutting force is required to shear titanium compared with past offerings, said Mitsui Seiki’s Walker. This change enables end users to achieve the same metal removal rate with less thrust. Cutting titanium with a machine tool that provides high torque and high-force axial feed capability is the strategy.

He added that toolmakers are producing cutting edges that can handle more heat while evacuating chips more efficiently, which enables higher cutting speeds. “In the old days, we would cut around 180 sfm. Today, they are at 340, 440, 540 sfm.” From a machine tool design standpoint, machine builders must increase the torque profile and be able to run at a higher rpm to increase the mrr, Walker said. “For example, back in the day when we were building hard-metal machines, we would have 2,000 ft.-lbs. of torque at 106 rpm.” When running at 300 rpm, the torque curve drops significantly and the torque becomes insufficient to maintain the same speeds and feeds, he added. “This means the gearboxes now need to be built to accommodate 2,000 ft.-lbs. at 400 rpm instead of 100 rpm. The gearboxes need to have wider gears and be more robust to be able to take the

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For instance, about 4,000 lbs. of thrust force on an axis is needed to remove about 20 in.³/min. compared with the previous requirement of 5,000 lbs., he added.

Another change is the necessity to have active damping in the machine to control chatter based on the longer range of cutting impact frequencies than in the past, Walker said.

Because cutting titanium at a peak performance level puts heavy demands on a machine tool, machine builders must rise to the occasion to remain competitive. Boeing Co., for instance, requires 98.5% spindle availability time, Walker said. “That means whenever you want to use the machine, 98.5% of the time it needs to be available to run. You need to monitor that asset and predict the maintenance schedules to fix things that are going to break before they break.”

**Power Monitor**
A monitoring system Mitsui Seiki installs on its machine tools is Tool

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Monitoring Adaptive Control from Caron Engineering Inc., Wells, Maine. TMAC monitors the spindle drive, and an increase in power indicates tool wear, said President Rob Caron. “We also do adaptive control, so we can take over the feed rate and achieve a constant power cut by modifying the feed rate in real time.”

He explained that the system monitors “true power” instead of current to provide a more linear signal over the range of the spindle motor load and function as a more accurate indicator.

“If the motor is lightly loaded, with current you don’t get a very linear signal or a very good representation of what is going on,” Caron said. “It’s much better when the motor is heavily loaded. By monitoring true power, your signal is absolutely linear whether you are monitoring a light cut or a heavy cut.”

By continuously monitoring the power drive, the system reduces the feed rate only when a cutting tool starts to load up or degrade or when the material thickness or hardness increases, Caron said. “So whenever we can go faster, we will, whereas without the system the customer has to program basically worst-case
scenario, never knowing when a thicker or harder spot is going to happen or when the tool is going to break down a little more.”

Feeding higher when appropriate enables end users to reduce cycle times. Caron Engineering doesn’t provide any guaranteed reduction but reports that it ranges from 20% to 60% with TMAC. “In the titanium area, it is rare to ever see under a 30% reduction,” Caron said. “The cycle time reduction gets higher as the materials get more challenging.”

Although successfully completing a titanium part can take precedence over speed, every aerospace company, for example, is being asked to reduce production costs, according to Caron, and tool monitoring is an effective way to minimize expensive parts becoming boat anchors. “We give them the ability to prevent scrapping a part by removing a tool when it is supposed to be removed.”

The system also helps overcome the challenge of finding workers with the ability to hear and understand when a tool breaks down, Caron added. “Typically, there needs to be an operator right there keeping an eye on the machine. We can do this type of work automatically, so it allows the machine to run unattended.”
ADDITIVE APPROACH

Tool blanks are printed to make cutters to machine titanium.

By Alan Richter

To demonstrate that additively manufactured steel cutting tools can machine Ti6Al4V equal to or better than their conventionally manufactured HSS counterparts, Jimmy Toton, a mechanical and manufacturing engineering Ph.D. candidate at the Royal Melbourne Institute of Technology in Australia, conducted research. Using laser metal deposition equipment at RMIT University’s Advanced Manufacturing Precinct, the director of which is Toton’s supervisor, professor Milan Brandt, Toton 3D-printed tool blanks with the chemical composition Fe-25Co15Mo. Sutton Tools Pty. Ltd., Thomas-town, Australia, then ground the blanks on a CNC tool and cutter grinder to produce endmills. Toton has worked at Sutton Tools as an intern.

According to the definition from the American National Standards Institute, the material is not technically HSS but closer to the definition for maraging steel. “It is carbon-free and strengthened by the precipitation of nanosized intermetallics through artificial aging,” Toton stated in an email.

Steve Dowey, technology manager at

about the author

Alan Richter is editor of CTE. Contact him at 847-714-0175 or alanr@ctemedia.com.
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Sutton Tools and a senior lecturer and industry fellow at RMIT University, said Toton targeted a substrate material that provides an intermediate high hot hardness between HSS and carbide.

“The substrate has thermomechanical properties that make it a suitable material for titanium machining, such as a higher hot hardness and resistance to thermal softening than all high-speed steel grades,” Toton added.

Printing with the material, however, wasn’t easy. “Creating a straight, long, thin cylinder without any defects was quite an interesting challenge, and Jimmy took that on and spent a long time optimizing the deposition conditions,” Dowey said.

To overcome the issues he faced in getting the deposited metal layers to print properly and bond strongly, Toton noted he employed high-temperature substrate heating to manipulate solid-state transformations with a microstructure during printing and prevent crack formation.

“All of optimization of printing doesn’t come in the manual,” Dowey said, adding that manufacturers of additive equipment are becoming better at providing more information. “It is a bit of a dark art.”

While a conventional sintered blank might be 98% dense, Dowey said the 3D-printed blanks are fully dense. But that difference didn’t create any issues when Sutton produced the tools. “It was pretty straightforward to make a cutting tool from it,” he said, noting that about five tools were made. “We followed conventional grinding practices.”

Dowey added that the selected tool geometry isn’t one that’s optimized for machining titanium but one that’s effective for cutting a variety of materials to demonstrate an
improvement over HSS in this application. The 3D-printed tools did show an improvement in tool life, he said, but he emphasized that a part manufacturer would realize significant cost savings only by boosting productivity and would not be extending tool life. “Saving CNC machining time is the crucial thing.”

Because laser metal deposition doesn’t provide sufficiently high resolution to print complex through-coolant holes, Dowey said the next project will focus on 3D printing through-coolant tool blanks via powder bed fusion. “The LMD process was more to prove the material. The powder bed process is more realistic in terms of volume and could potentially provide a tool that we could economically sell. Right now, LMD is not economical.”

Toton explained that economic considerations played a major role in deciding to initially print blanks by LMD. With powder bed fusion, the machines at RMIT University require enough powder to fill the entire build volume, or at least 30 kg. In contrast, LMD can be performed with a few hundred grams of powder.

“As my material is experimental, a single batch is incredibly expensive,” he stated. “My aim was to develop a process methodology to manufacture cylindrical bars with the right microstructure, mechanical properties and wear resistance when machining titanium alloy Ti6Al4V, a proof of concept.

From this position, you are more likely to attract the research dollars needed to develop the IP for PBF.”

His LMD research, however, has already attracted dollars. RMIT University reported that Toton received the 2019 Young Defence Innovator Award, which comes with a 15,000 Australian dollar ($10,678) prize. “I am currently planning a much deserved trip to Europe,” Toton noted about the prize money.
Extended-reach toolholders remain a requirement for some jobs.

By Holly B. Martin

Because of interference, such as from a machine spindle snout, getting into certain features on a vertical machining center sometimes requires toolholders with long gauge lengths, said Jack Burley, vice president of sales and engineering at BIG KAISER Precision Tooling Inc., Hoffman Estates, Illinois. The minimum Z-axis, which is the closest distance a spindle can be to the worktable, has to be made up by the length of the toolholder. In the case of a horizontal machining center, the shortest distance a spindle can be to the center of the table is also a dead zone that has to be made up by the toolholder, he said.

“At least 90% of the time, catalog toolholders typically in the range of 2” to 6” or 8” are more than long enough to overcome these minimum strokes, dead zones or any other problems with machine limits,” Burley said. “It gets down to 10% of the problems—where either the parts are just so small or so close to the table or it’s on a horizontal where you have to reach across to the opposite side because of the feature that you’re trying to get to—where you need extended-reach toolholders.”

All the recent investment in multiple-axis machines, with their increased accessibility to workpieces, has made many people believe that the need for extended-reach toolholders is greatly reduced if not eliminated.

“With the 5-axis, I can tilt things around to get into those places using a standard toolholder, but you’re always working off the center of the table,” Burley said. “So everywhere around it, there are going to be certain tilts that make it difficult to reach, like the B-axis all the way at 90° to the spindle, and some features down by the table itself.”

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For situations like those, he thinks that extended-length toolholders always will be needed.

Optimal Length

CAM software tells a programmer the maximum and minimum gauge length from the spindle to the tip of the tool, Burley said. To determine other toolholder dimensions, a program’s collision detection system would calculate the maximum outside diameter of the toolholder and the optimum lengths to reach the longest conditions.

But what exactly makes a toolholder qualify as extended reach? “Extended reach is not just how long it is but how long it is in relation to the tool diameter,” said Gregg Bishop, general manager of Ultra-Dex USA, Flushing, Michigan.

He considers extended reach to be any toolholder longer than five to seven times the diameter. “It’s important that we keep those two things related,” he said. “So if we’re talking about 14” of reach and the tool diameter is only ½”, we have a ratio of 28 times the diameter. But

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a 2”-dia. tool at 14” length is only a 7:1 ratio, which is not particularly extended length.”

**Extended-Reach Machining**

Bishop said customers typically use extended-length holders to reach past fixtures, obstructions or part features to machine other part features beyond. For those applications, he recommends keeping cutting forces light to minimize radial or axial radial deflection.

“The cutting tool chosen could be more positive or high shearing,” he said. “Or we can apply toolpaths, such as high-efficiency or high-feed milling, which are different approaches to speeds and feeds and depth of cut.”

Trochoidal milling, a form of high-efficiency milling, is one option for extended-length toolholders because it exerts less stress on the spindle.

“The idea for a 1”-wide slot is to use a smaller-diameter cutting tool, like a ½” milling cutter instead of a 1” cutter, and then feed the cutter forward in a circular toolpath opening the slot to the 1” width instead of creating it with one big hog pass that’s 1” wide,” said Mark Backus, product specialist for machine integration and tooling systems at Sandvik Coromant Co., Fair Lawn, New Jersey.

The main challenge with extended-reaching toolholders is achieving suitable rigidity. The longer and thinner the holder, the more likely that bending forces will cause runout.

“ ‘Extended reach is not just how long it is but how long it is in relation to the tool diameter.’

‘The tool steel itself, along with the Rockwell hardness of the tool steel and the substrate, all relate to the rigidity of the tool assembly,’ Bishop said. “Let’s say you try

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**about the author**

Holly B. Martin is a science writer and technical copywriter based in Winchester, Virginia. For more information, visit www.hollybmartin.com.
to reach something out 12”. You’ve got to start with good runout, and a shrink-fit holder is the smartest choice for that application. Instead of having a toolholder with set-screws on the side of it that pushes a tool one direction or the other, a shrink-fit holder actually wraps right around it, giving you the optimal runout, which is below a tenth.”

Going Modular
As an option to a single-piece, extended-length holder, several companies offer modular systems that can be built to longer lengths as needed.

“We can build specials beyond the normal catalog size or range, which is usually after 8” or 6” on smaller-taper tools,” Burley said. “But my preference is to direct people toward our CKB line of modular mill/turn tools for mill/turn centers.”

The advantage of the modular concept, according to Burley, is that there are hundreds of different components that can be assembled together. A CAD/CAM programmer can choose from these to create the optimal tool configuration to fit into the reach and meet the needs of the program.

“It’s kind of like Legos where you start with a basic holder and you...
The Need for Extended-Reach Boring Bars

Vibration-damping technologies are for not just longer-length toolholders but boring bars.

“There’s a ton of demand in the oil and gas industry to get much deeper into a bore for ID turning,” said Gregg Bishop of Ultra-Dex USA. “They’re always trying to push that envelope to reach size and finish limits we never thought were possible. Imagine a 40” bore with a standard 4” bar. You can’t do that with a traditional carbide shank boring bar.”

He said oil and gas applications use threads with a high insert engagement, which creates a lot of deflection when cutting, and therefore vibration occurs even at short bar lengths.

In response to demand, Ultra-Dex developed a chatter-free line of boring bars with up to a 14-1 ratio. These long-overhang ratios are made possible by an internal damping technology based on a high-density alloy that provides optimal dynamic stability.

“They can run at higher speeds and feeds versus a plain carbide or steel boring bar with the same hangout ratios,” Bishop said. “It’s a productivity booster, so the (return on investment) on the added cost is found where the customer takes into consideration the increased throughput.”

—Holly B. Martin
can extend it and taper it and do all kinds of things to make it the way you want it to look using standard components,” Burley said. “And the beauty of that is, because you’re using a pool of common components, you can take it apart whenever the job is over and reuse the parts for other builds.”

A modular system normally consists of basic holders with extensions, reductions and toolholder components that fit into them, such as shell mill, collet chuck or endmill holders.

Coromant Capto by Sandvik is another modular system that can be used to create extended-length toolholders. “You can use a Coromant Capto adapter on the machine spindle side and then put different types of milling cutters, drills or boring heads on the machining side of the assembly end of the adapter,” Backus said. “You can add more extensions to make it longer and stack them out as far as you need. On the same tool assembly, you can have different diameters, which gives you a lot of versatility. You usually would start with a larger diameter at the base and then reduce it to whatever you need or just keep it all the same diameter for the entire assembly.”

Of course, modular toolholders bring their own challenges.

“You will sacrifice a little bit of accuracy when you start building up these components, but they’re designed in such a way as to remove the inaccuracy of each connection,” Burley said. “We’ve actually stacked together four or five parts and measured the (total indicator runout) at almost 12” and seen runouts that are less than 0.0005”, which is extremely good for any tool.”
Customers also may worry that a modular toolholder is not as rigid as a single-piece one.

“It’s not as good as a solid tool,” Burley said. “But in some situations, because I can build it based on the configuration that I want, I can make it stiffer and larger than a 12” standard holder that is long and slender.” That scenario is where the versatility of a modular toolholder comes in handy.

“If you’ve got to go around the side of a workpiece but the first 6” is in the dead zone, then we’re going to make that zone as beefy as we can,” Burley said. “Compared to a one-piece holder of exactly the same length and the same exact shape, the rigidity wouldn’t be as good as the solid tool, but I would put it within about 10% of the same range.”

Several companies provide holders with vibration-damping technologies.

“The further the overhang of the tool assembly, the more vibration will be introduced,” Backus said. “If they’re taking a light cut with a milling cutter or they’re drilling, they may get by with a pretty long assembly. But if they’re doing a heavier cut with the milling cutter, they need something like our Silent Tools milling adapter to dampen the vibration.”

Anti-vibration technologies typically are based on a damping mass, which is often a heavy metal, a fluid or both inside a holder to offset vibrations.

“In many cases,” Backus said, “with our vibration-damping toolholders for turning, boring or milling, it can be a great productivity booster without needing to make

![Image of composite routers]

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Finding the Sweet Spot

With an extended-reach toolholder, end users must contend with physics. Due to bending forces and frequencies, a 12"-long tool never can run as fast or hard as a 2"-long tool, Burley said.

“Every tool system and spindle has a natural frequency,” he said. “And when you run a tool that is coincident to that frequency, you get a lot of vibration.”

One way to avoid the problem is to reduce the spindle speed until exiting the coincidence zone.

“But even though the instinct is to slow down when something vibrates, there are certain situations where if you go faster, you also run into a sweet zone that (doesn’t) get the chatter,” Burley said. “And extended-reach toolholders have these bands just as much as the shorter ones. They’re narrower but still exist.”

For example, he said if a 6"-long tool chatters at 2,000 rpm, a 7"-long tool might not because the 6"-long holder at that rpm is coincident to the natural frequency of the system while the 7"-long holder is out of phase.
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CNC machines loaded with indexable tools are the foundation of modern machining.

By Christopher Tate

Over time, innovative products and ideas have been introduced that significantly altered the landscape of machining. Screw cutting lathes, EDMs, CNCs, CAD/CAM software and lasers are all milestone technologies on the manufacturing timeline.

In the 1920s, scientists and engineers brought cemented carbides to the market. That substantially affected the path of metalcutting, not only boosting productivity but changing machine tool design. Shortly after cemented carbides arrived, so did the tools we commonly refer to as inserts.

CNC machine tools, EDMs and lasers are far more exciting than carbide inserts, and it is easy to see how these technologies have helped manufacturing. However, the common carbide insert may well have had a much larger impact than all the other developments combined.

Before inserts, cutting tools had to be sharpened when dulled. This required them to be removed from a machine tool and transported to another location where someone would manually grind them to restore cutting edges. Today, we recognize the disadvantages of having to take off tools for sharpening. Increased tool inventories, lost production and longer setup times are just some of the downsides. The introduction of carbide inserts changed all this. A person now simply indexes, or turns, an insert to a fresh cutting edge or replaces a fully worn insert, and a machine tool is ready to run with no setup and minimal adjustment.

Variety is another advantage of carbide inserts. Before, tools were typically solid HSS or had steel shanks with carbide pads brazed on the end. Variation in workpiece materials requires variation in cutting tool materials. So HSS and brazed tools are manufactured with different recipes, thereby producing multiple grades...
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with various levels of hardness and toughness. While many grades of HSS and brazed tools are available, inserts are manufactured in countless grades and new grades are continually added, giving far more options to users than HSS or brazed technologies.

The Incredible Insert

Inserts also provide advanced chip control geometries that can be paired with a specific substrate and coating to further enhance tool performance. Previously, HSS and brazed tools required users to add chip grooves to the rake face if chip control was necessary. This added to the complexity of reconditioning and often was done by hand, which provided varying results. With inserts, users can open a tool manu-

This is one of the largest drills at Mitsubishi Hitachi Power Systems Americas. The drill uses three inserts, and about 10 minutes is needed to change all three. A special piece of grinding equipment and several hours would be required to sharpen an HSS drill this large.
facturer’s catalog and select from a vast array of geometries. More importantly, when a user develops a machining process, a manufacturer can offer several geometries for testing, making the development process much quicker and easier.

Indexable-insert tools come standard in many shapes and sizes so users can perform almost any machining operation with off-the-shelf tools. Inserts with diamond, triangle, round, square and thread shapes are common and easily sourced anywhere in the industrialized world. The worst case is next-day delivery on a truck.

On the other hand, HSS turning tools, also known as tool bits, can be ground to any shape imaginable. And brazed tools can be made into any shape that a carbide tip allows, so they may be slightly more universal. However, someone must machine these tools before they can be applied, which is undesirable in today’s manufacturing environment.

Inserts and indexable tools have a distinct cost advantage over other types of cutting tools. Drills and endmills are a good example. Typically, tools that are larger than 1” in diameter are expensive. Production-oriented shops might need several large HSS drills to ensure that production does not stop when tools become dull, because sharpening is done outside the machine tool and often sent off-site. But change the HSS drill for an indexable-insert drill, and now a shop may need only one tool. When it is dull, a user simply rotates or replaces the insert without removing the tool from the machine and frequently without resetting the machine. The result is less downtime, reduced cost of tool ownership and fewer opportunities for mistakes when resetting the tool. For very large tools, such as the 80mm-dia. x 600mm-long drills we use at Savannah (Georgia) Machinery Works, indexable tools are the only thing available because it does not make economic sense to buy such a large HSS drill.

The Effects of Inserts
Indexable tools have driven

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**about the author**

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changes to machine tool design and vice versa. Although some inserts are up-sharp for nonferrous applications, inserts are typically less sharp than round tools produced by grinding and must operate at higher cutting speeds and chip loads than sharper tools or they will, theoretically, not perform effectively. Machine tool builders started to realize that sales would depend on the ability of a machine to turn at the spindle speed necessary to achieve proper cutting speeds and the rigidity needed to push the tool at the desired feed rates. As CNC machines began to proliferate, they became faster and more rigid to ensure that cutting tool performance would not be limited by the machines, but insert manufacturers also had to catch up with machine tool developments to take advantage of machine advancements and maximize productivity.

Controls also advanced. Most of the early adopters of CNC technology used machines much like old turret lathes and tracer mills, relying on form tools made by hand to create complex geometries. Controls began to progress, and the creation of complex toolpaths became much easier—so easy that many programs today are created on shop floors. Although several factors reduced the need for form tools, the fact that a machine could create almost any desired shape with a single indexable tool significantly drove development of controls. It could be argued that they would have progressed anyway, but the advances most likely would have been slower.

It is impossible to imagine a machine shop without indexable tools. After 80-ish years, I suspect that no one is left who can remember machining without them. CNC machines loaded with indexable tools are the foundation of modern machining and will be well into the future. When additive manufacturing is perfected, the insert will still remain an invaluable tool.

The common carbide insert may well have had a much larger impact than all the other developments combined.

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**Inside Inserts**

CTE
Boring is an internal turning operation performed with a boring bar to enlarge a previously drilled hole to form an internal shape of specified dimensions. Boring operations range from semi-roughing to finishing.

A boring bar has three basic elements: an indexable cutting insert, a shank and an anchor. The designation system for indexable inserts is the same as for turning. The anchor is the clamping portion of the shank that is held in the tool block, and the minimum clamping length is approximately three to four diameters of the shank. The distance the boring bar extends beyond the tool block, which is called overhang, determines the cutting depth. The overhang is the unsupported portion of the boring bar. Long overhang causes excessive deflection of the shank and generates vibration, or chatter, which deteriorates the surface finish of the bore.

Eliminating chatter, especially when boring deep holes, is one of the greatest challenges faced by manufacturers and users of boring bars. Deflection of a boring bar depends on the mechanical properties of the shank material, the length of the overhang and the cutting conditions.

The following equation is used to calculate deflection (y) of a boring bar:

\[ y = \frac{FL^3}{3EI} \]  

Where

- \( F \) is the cutting force, lbf or N.
- \( L \) is the unsupported length of a boring bar (overhang), in. or mm.
- \( E \) is the modulus of elasticity (in tension) of a boring bar material, psi or N/mm².
- \( I \) is the moment of inertia of a boring bar cross section area, in.⁴ or mm⁴.

**Cutting Force**

Cutting force (F) expressed in customary U.S. units of measure, calculated by formula (2):

\[ F = 396,000 \times d \times f \times K_p \times C \]  

Where

- \( d \) is the bore diameter, in.
- \( f \) is the feed per revolution, in. per revolution.
- \( K_p \) is the depth of cut factor.
- \( C \) is the cutting fluid factor.
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Boring Bar None

The number 396,000 is expressed through:
- A unit of power equal to 550 ft.-lbs./sec.: 550.
- A unit of power equal to 550 ft.-lbs./min.: 550 × 60 = 33,000.
- A unit of power equal to 550 in.-lbs./min.: 33,000 × 12 = 396,000.

\(d\) is DOC, in.
\(f\) is a feed rate, ipm.
\(K_p\) is a power constant, hp/in.\(^3\)/min.
\(C\) is the feed rate factor for the power constant adjustment.

Example of calculating the cutting force (F)

Given:
The workpiece is AISI 4140 chromium-molybdenum steel, 220 to 240 HB.

\[\text{DOC, } d = 0.08\text{"}.\]
\[\text{Feed rate, } f = 0.008 \text{ ipr.}\]
\[\text{Power constant, } K_p = 0.76 \text{ hp/in.}^3/\text{min.}\]

Feed factor, \(C\) = 1.08.
Adjusted power constant, \(K_{pa} = K_p \times C = 0.76 \times 1.08 = 0.82\).

Calculating:

\[F = 396,000 \times d \times f \times K_{pa} = 396,000 \times 0.08 \times 0.008 \times 0.82 = 207.8 \text{ lbf}\]

Cutting force (F) expressed in metric units of measure, calculated by formula (3).

\[F = 60,000 \times d \times f \times K_p \times C \quad (3)\]
Where

The number 60,000 is expressed through:
- A unit of power equal to 1kW × m/sec.: 1.
- A unit of power equal to 1kW × m/min.: 1 × 60 = 60.
- A unit of power equal to 1kW × mm/min.: 1,000 × 60 = 60,000.

\(d\) is DOC, mm.
\(f\) is a feed rate, mm/min.
\(K_p\) is a power constant, kW/cm\(^3\)/min.

\(C\) is the feed rate factor for the power constant adjustment.

Comparing the data of the cutting forces, we can say that formulas (2) and (3) provide sufficient accuracy.

By converting the cutting force of 207.8 lbf (customary U.S. units of measure) into metric units of measure, we get:

\[F = 207.8 \times 4.448 = 924.3 \text{ N} \quad \text{(compare with 911.1 N)}\]

The difference is:

924.3 N - 911.1 N = 13.2 N, or 1.4%.

By converting the cutting force of 911.1 N (metric units of measure) into customary U.S. units of measure, we get:

\[F = 911.1 \text{ N} \times 0.2248 = 204.8 \text{ lbf} \quad \text{(compare with 207.8 lbf)}\]

The difference is:

207.8 lbf - 204.8 lbf = 3 lbf, or 1.4%.

Moduli of Elasticity

Boring bar shanks are made of...
steel, tungsten-base alloys or cemented carbide. The most frequently used boring bar material is alloy steel. Some boring bar manufacturers use AISI 1144 free-machining medium-carbon steel. Regardless of their grades, all carbon and alloy steels have the same modulus of elasticity:

Customary U.S. units of measure:

\[ E = 30 \times 10^6 \text{ psi} \]

Metric units of measure:

\[ E = 20.6 \times 10^9 \text{ N/mm}^2 \]

A common mistake is to assume that a steel shank with a higher hardness or a steel shank made from higher-quality steel will deflect less. As can be seen from equation (1), the material property that determines deflection is the modulus of elasticity. Hardness does not appear in this equation.

Tungsten heavy alloys for boring bars have the same modulus of elasticity:

Customary U.S. units of measure:

\[ E = (45 \text{ to } 48) \times 10^6 \text{ psi} \]

Metric units of measure:

\[ E = (31 \text{ to } 33) \times 10^4 \text{ N/mm}^2 \]

Boring bars made of tungsten heavy alloys will deflect less than steel boring bars of the same diameter and overhang by 50% to 60% when cutting at the same DOC and feed rate.

Cemented carbides for boring bars have the same modulus of elasticity:

Customary U.S. units of measure:

\[ E = (84 \text{ to } 89) \times 10^6 \text{ psi} \]

Metric units of measure:

\[ E = (52 \text{ to } 61) \times 10^4 \text{ N/mm}^2 \]
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Boring bars made of cemented carbide provide minimum deflection because their moduli of elasticity are higher than those of steel and tungsten heavy alloys.

Moment of Inertia

The moment of inertia is a property of areas. Because boring bars are available in various diameters, it is important to calculate the area of a bar cross section using appropriate formulas. A boring bar is usually round with a solid or tubular cross section. The moment of inertia of a solid cross section area is calculated by:

\[ I = \pi \times \left( D_0^4 - D_i^4 \right) / 64 \]  
Where \( D_0 \) is a bar OD in in. or mm. Moment of inertia of a tubular cross section area is calculated by:

\[ I = \pi \times D_0^4 / 64 \]  
Where \( D_i \) is a bar ID in in. or mm.

Example of calculating the moment of inertia \( I \) (customary U.S. units of measure)

Given: Outside diameter is 1”. The moment of inertia is calculated using formula (6).

\[ I = \pi \times 1^4 / 64 \approx 0.0491 \text{ in.}^4 \]

Example of calculating the moment of inertia \( I \) (metric units of measure)

Given: OD is 25.4mm. The moment of inertia is calculated using formula (6).

\[ I = \pi \times 25.4^4 / 64 = \pi \times 416,231.4 / 64 = \pi \times 6,503.6 \approx 20,432 \text{ mm}^4 \]

Deflection

Example 1: Unsupported length of a boring bar (overhang), \( L = 4" \).

Calculating deflection of the bar (customary U.S. units of measure)

\[ y = FL^3 / 3EI = 207.8 \times 4^3 / 3 \times 30 \times 10^6 \times 0.0491 = 12,652.8 + 4,419,000 = 0.003" \]

Example 2: Unsupported length of a boring bar (overhang), \( L = 101.6 \text{mm} \)

Calculating deflection of the boring bar (metric units of measure)

\[ y = FL^3 / 3EI = 911.1 \times 101.6^3 / 3 \times 20.6 \times 10^4 \times 20,432 = 955,536,257 / 3 \times 4,208,992,000 = 0.0757\text{mm} \]

Let’s compare: Deflection of the boring bar in example 1 is 0.003”, or 0.0762mm, and deflection of the boring bar in example 2 is 0.0757mm, or 0.00298”.

To help ensure a successful boring operation, the overhang should be as short as possible to minimize boring bar deflection. In addition, the boring bar should be made of either tungsten heavy alloy or cemented carbide, and the bar diameter should be as large as possible to achieve the maximum moment of inertia.

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A part manufacturer must have confidence in its cutting tools to successfully perform lights-out machining. “When we can’t trust a tool, we can’t do it, so we lose production,” said Ben Sacco, operation manager for Radax Industries Inc.

Unfortunately, the Webster, New York-based fastener manufacturer and provider of machining services didn’t have enough confidence in the rotary broaches it was applying to allow long, unattended production runs. For example, Radax averaged 500 pieces per broach, which cost $100 each, when machining 17-4 PH stainless steel before the tool would chip and need replacement, Sacco said.

“I just couldn’t swallow that cost much longer. It was getting ridiculous,” he said, noting that Radax doesn’t typically run low-volume jobs at its 50,000-sq.-ft. facility. “We have long, ongoing jobs that never come off the machine.”

Of course, reaching that level didn’t happen overnight. Sacco’s grandfather Rocco founded the company in 1967, operating three Davenport screw machines in a
rented barn in rural upstate New York. The “office” was a pay phone in a bar across the street, Sacco said. “The bartender would run across the street when the phone started ringing and say, ‘Hey, Rock, you’ve got a phone call.’”

With Radax doing more business than ever in the present day, it couldn’t afford to have a weak machining link, Sacco said. He previously found that a rotary broach that lasted for 500 pieces when cutting 17-4 PH stainless, which tends to workharden and dull edges, was the best available. Then, he learned about the rotary broaches from Rayco Tools Inc., Warsaw, Indiana. Sacco read testimonials about Rayco’s broaches on LinkedIn and contacted Chris Rooney, the toolmaker’s owner and president, who sent three free broaches to test. Of those, Rayco #7 proved most
effective, Sacco said, and Radax immediately ordered more.

Rooney stated that Rayco #7 is made of a special-purpose HSS that exhibits high hardness, enhanced abrasion resistance and toughness. The broach is suitable for machining materials with tensile strengths exceeding 190 ksi and a hardness up to 50 HRC. But he emphasized that having a source for the substrate won’t enable another toolmaker to duplicate the performance of Rayco broaches.

“It’s not the HSS material but the Rayco heat-treat process that makes all the difference,” Rooney noted. “Our process creates a finer grain structure at a higher hardness while maintaining the toughness. Conventional heat-treated HSS creates this fine structure but at a lower hardness, therefore lacking the wear resistance compared to a Rayco heat-treated broach.”

Although Sacco has broached up to 1,800 parts made of 17-4 PH stainless with a Rayco #7, he normally replaces the broach after the counter on the control of a Tsugami Swiss-style machine reaches 1,000 pieces. “We know if we pull it out at that time, there is virtually no cause for failure, and we just keep running,” he said. “That way, we have zero defects.”

That point isn’t the end of a tool’s life, however. Radax refaces used broaches and applies them when workers are present at a machine, Sacco said. “The tool life is almost the same, but I don’t want to push it.”

In addition to lasting twice as long as the previous rotary broach, Sacco said Rayco #7 broaches cost 25% less. “These #7 tools give us the ability to run longer production runs overnight without having to worry about a heap of scrap in the morning. We had no confidence before—zero.”

He said Radax also applies the broach to machine a variety of other metals, including titanium and S-7, 15-5 and 316 stainless. “I’ve switched all our broaches to Rayco.”

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PEOPLE

- Machine tool builder Index Corp., Noblesville, Indiana, hired Mark Smith as Midwest sales representative.
- Metrology equipment manufacturer Mahr Inc., Providence, Rhode Island, appointed people to a number of senior-level positions, including Chris Wichern, product manager for 3D surface metrology; National Distribution Manager Brad Frost; Dan Cavaliere, customer resource center manager; Rebekah Bruhn, health, safety, environmental and quality manager; Regional Sales Manager Doug Klein; Michael Plante, project manager of engineered solutions; and District Sales Manager Tim Prentice. Mahr also opened a demonstration center in Greenville, South Carolina, and a customer center in Wixom, Michigan.
- Auburn, Massachusetts-based Physik Instrumente LP, which specializes in air bearing stages, piezoelectric solutions, motion control equipment and hexapod parallel kinematics, appointed Dave Rego vice president and general manager of North American operations.

COMPANIES

- Birmingham, England-based Precision Micro Ltd., which manufactures photo etching components, promoted Karl Hollis to director of engineering.
- Manufacturers representative The Whittemore Co., Addison, Illinois, partnered with Mundelein, Illinois-based Lyndex-Nikken Inc. to represent its toolholders, chucks and other machining products in Minnesota, North Dakota, South Dakota, Iowa, Nebraska, Missouri and Kansas. Whittemore also partnered with Hoffman Estates, Illinois-based NSK America Corp. to represent its machine tool spindles and hand tools in Illinois and Wisconsin. Also, Whittemore expanded partnerships with toolmaker Dormer Pramet, Elgin, Illinois, to represent the company in Wisconsin and with Washington Court House, Ohio-based Riten Industries Inc., which manufactures live centers, dead centers and face drivers, to represent the company in Kansas and Missouri.
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FOCUSING ON HIGH-SPEED INSPECTION

By Robert Weinstein

Manufacturers continually look to improve the quality and speed of their inspections. The new Taglens-T1 varifocal lens by metrology manufacturer Mitutoyo America Corp., Aurora, Illinois, promises a significant advancement in the field.

“The Taglens-T1 provides high-throughput noncontact inspection,” said Paul Nuara, optical product specialist at Mitutoyo America, adding that the variable-focus lens does not require mechanical refocusing.

The technology initially was developed by a team led by Princeton University professor Craig B. Arnold, an expert in materials science and lasers. The group began to commercialize the technology in 2011 through Princeton, New Jersey-based Tag Optics Inc., which was co-founded by Arnold and Princeton University alumnus Christian Theriault. In 2016, Mitutoyo purchased a controlling interest in Tag Optics.

Taglens-T1 is optical, not laser-based, and it has no probe.

“It contains a proprietary liquid within a glass lens,” Nuara said. “The Taglens controller generates sound in the liquid, changing its optical properties.”

The lens is less affected by vibration and shock than competing devices and can be mounted on robotic arms, according to Mitutoyo.

When an image is created without Taglens technology, generally one element is in sharp focus, and the rest are out of focus. Taglens-T1 allows the entire image to be in sharp focus in a given scanning range, depending on the field of the optics.

The technology is able to scan the full range of the lens every 14 microseconds at 70 kHz. The depth-of-field expansion eliminates the need for mechanical refocusing, unlike with fixed focal-length optics.

The growing use of CNCs and robotics has led to increased manufacturing of parts with complex geometry. Nuara said by expanding the depth of field, Taglens-T1 will prove useful when inspecting these parts, especially electronics and medical parts.

“The Taglens-T1 is ideal for use throughout the manufacturing process,” he said, noting that the technology can be used for inspection at the beginning of a run to enable any adjustments needed for manufacturing, as well as for post-manufacturing QC.

“It provides more qualitative data per unit of time,” Nuara said. “There are other companies that offer liquid lenses, but the advantage of the Taglens-T1 is that there is no loss of performance when the lens is inverted or the orientation is changed as are often needed when inspecting complex parts.”

The lenses are manufactured in the U.S. and then sent to Japan for packaging and distribution. Mitutoyo’s product line includes video microscope units, such as VMU-T1, which incorporates Taglens-T1. In addition, the lens can come with an optional software development kit so end users can consolidate the data the system generates into their own software. Nuara said future development of the product line likely will integrate the lens into other measurement systems, like vision systems and microscopes.

For more information about Mitutoyo America, call 888-648-8869 or visit www.mitutoyo.com.

about the author
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