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2. Your job title (check one):
   1. Corporate Manager
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   2. Engineering Manager
      (Supervise Engineering Personnel);
   3. Engineering Department
      (Non-Supervisory Position);
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   5. Production Department
      (Non-Supervisory Position);
   6. Design, R&D;
   7. Purchasing;
   8. Quality Assurance, Control;
   9. Other (please specify)

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<td>337 Furniture and Related Product Manufacturing</td>
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<td>339 Miscellaneous Manufacturing</td>
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<td>423 Wholesale/Trade/Durable Goods</td>
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<td>999 Other Manufacturing NEC</td>
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| 3b. If your company does NOT manufacture AT THIS LOCATION, specify company’s primary product or service performed. (please specify) |

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<th>4. Number of employees at your company.</th>
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A video supplement to June’s Shop Operations column outlines how to achieve a high material removal rate while maintaining a reliable cut using a light-duty machine.

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Learn how a New York shop boosted productivity and improved worker safety by implementing an automated material handling system that loads and unloads railway wheels in need of repair.

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The 102nd episode of Ask the Grinding Doc covers the impact that thermal softening, residual tensile stresses and rehardening burn have on fatigue life with steel workpieces.

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Join us in congratulating Emuge-Franken on its 100th anniversary. It all started in 1920 when German engineer Richard Glimpel invented a single-finishing tap with a spiral point for thread manufacturing. He then founded what would become Emuge with three employees. Today, the company employs more than 1,900 worldwide. See this and more on CTE social media.
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With the official cancellation of IMTS 2020, I think this may be an appropriate time to share some good news regarding COVID-19’s impact on the industry. While not in the lighthearted vein of actor John Krasinski’s YouTube series, I am certain that the results from our 2020 Benefits and Salary Survey will lift your spirits — particularly the data gathered about the pandemic.

More than 97% of companies surveyed among Cutting Tool Engineering’s subscribers reported that they remain open for business. For the record, 103 companies that receive our magazine participated in the biennial survey. Of those, 74 graciously answered optional questions related to the pandemic.

In other words, just two companies had shut down due to the coronavirus.

Of the 72 companies that remained open, 78% said they were “fully” open, and the remaining 22% were open on a “limited basis.”

Although a clear majority remained fully open, nearly half the companies said their workload was down 40% or more. A fourth of respondents said business was down 20%.

In a glimmer of hope, 22% of respondents said business had remained about the same while 5% reported an increase in business.

In addition, 76% of companies said they have not had to lay off or furlough employees due to the pandemic. Although that means that 24% have had layoffs or furloughs, I must admit I expected those results to be the other way around.

What makes these results even more hopeful, at least for subscribers, is that we didn’t limit the survey to subscriber companies this year as we normally do. To ensure we would get enough respondents despite the pandemic, we turned to the company we use to collect data for the survey, SurveyMonkey, to increase the number of respondents. We paid SurveyMonkey to target members of its survey panels in the manufacturing industry. In a matter of days, SurveyMonkey delivered more than 200 additional respondents.

The thing is, pandemic-related results from subscriber companies are significantly better than the data gathered from SurveyMonkey’s manufacturing survey panels. Nearly 28% of respondents obtained by SurveyMonkey said their companies were shut down. Of the companies that remained open, just 64% reported being fully open.

Respondents obtained by SurveyMonkey reported a workload experience similar to that of CTE subscriber companies. Unfortunately, 54% of SurveyMonkey respondents said their companies have had to lay off or furlough employees due to the pandemic.

While CTE will provide a more detailed report on these results in August’s issue, I wanted to share some results now because I hope they help you rise above the gloom and doom and realize that a great deal of the industry is still going to work every day and working hard.

We all have roles to play in this industry. CTE will continue to do its part for companies working through the pandemic, which, again, is nearly our entire subscriber base. Hats off to all of you.

Dennis Spaeth is CEO and publisher of CTE. Contact him at 847-714-0176 or dspaeth@ctemedia.com.
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Metalworking Product Review

THREE-FINGER GRIPPER HAS LARGE STROKE: The 3FG15 three-finger gripper from OnRobot Americas has a maximum stroke of 150 mm (5.9"). The electric gripper has a 15 kg (33.1 lb.) payload and provides a strong, stable grip for both form fit (internal) and friction fit (external) gripping. The design was developed for machine tending, and the gripper automatically centers workpieces. OnRobot Americas; www.onrobot.com

SAFETY NOSING GLOWS IN DARK: Wooster Products Inc.’s Niteglow treads are for exit path markings, steps and the leading edge of landings when finding pathways in the dark is necessary. The two-stage, anti-slip stair nosing has a heat-treated, corrosion-resistant aluminum substrate and a hard aluminum-oxide filler for long tread life. Bright photoluminescent epoxy filler is free of hazardous, radioactive substances. Wooster Products Inc.; www.woosterproducts.com

VIRTUAL MACHINING CENTER FOR SMALL PARTS: The 215.9 mm × 685.8 mm (8.5" × 27") No. 9680185 VMC from Palmgren provides an economical solution for machining small parts. An automatic toolchanger and eight-tool magazine make the VMC suitable for prototyping and short runs. Standard features include linear guides, servodrives and ballscrews on all three axes, as well as safety switches on all doors for improved safety while machining. Palmgren; www.palmgren.com

DRILLING/TAPPING CENTERS FOR HIGH-VOLUME APPLICATIONS: Absolute Machine Tools Inc. offers the Tongtai VTX series of drilling and tapping centers, which have a 2,210 mm × 1,600 mm (87" × 63") footprint. The machines have a fixed column/moving table-type design with Meehanite cast-iron frames and roller-type linear slideways. The standard 12,000 rpm, direct-drive spindle provides rigid tap speeds up to 6,000 rpm. Absolute Machine Tools Inc.; www.absolutemachine.com
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On my first day at my machine shop, I had money in the bank, jobs on the floor, an experienced crew, working machines and customers. Everybody knew what they needed to do, and we had tooling for every job. Better yet, I made money on each job. There was no “I have to buy $100 in tools to do a $200 job” to suck up all the profit and then some. This may sound like a shop fantasy. But I was able to do it because I bought an established, working shop, which was far easier than starting one from scratch. I know this because I twice had tried to start a business by myself.

When I worked for a large defense contractor, I traveled the country checking on jobs subcontracted to family-owned shops. I saw families doing very well for themselves, and I wanted that for my family too. So I formed a company nearly 25 years ago. As a degreed engineer, I began with a business that required almost nothing except a professional engineering license: a manufacturing engineering consultancy. It went well, and I made more money than when working for someone else. However, the travel and time away from home were hard on my young family. It didn’t make sense to risk losing the people I was trying to do something good for, so when a client offered a permanent job to me, I took it.

For my second attempt six years later, while still employed, I chose to start a shop so I would not have to travel frequently. I rented a space and began the grueling task of calling on customers, planning and running jobs, packaging and delivering, programming and purchasing tools. I found that profits mostly went toward buying tools. Also, I was away from my family in evenings. I reached a point at which the business provided 30% to 50% of my salary, but my waking hours were 100% gone. It’s a moment that many “evening startups” experience. I had to decide whether to leave my day job and commit to the startup at perhaps half my regular wages or continue both endeavors and exhaust myself. In the end, I sold my business to an established competitor in my town.

As the saying goes, the third time was the charm. While working for another defense contractor, I passed a shop and was curious what it did. I believe in miracles, and this qualifies in my mind. The shop had been in business on the same site in Pittsburgh since 1906. The founding family owned the company, but no heir was interested in taking over. It had been for sale for six months and was about to be torn apart for an auction. The machines were a bit dated, but there were customers and experienced employees, and it was a profitable business.

The owners shared their previous five years of financial data. After three months of coming in weekly, reviewing operations and records and talking to banks — a period that professionals call due diligence — my family took money from our life savings and put down 20% on the business, including its facility. Four years later, we have updated the machinery, we are financially strong, and I see my family every night. I consistently work 10-hour days but only because I want to, and that still beats the 14-hour days of a startup.

If you want to own a shop, think about talking respectfully to older shop owners in your area. They may be looking to retire and cash in on their life’s work, and you may be the person who can provide an exit strategy.

**about the author**

Matthew Mawhinney is general manager at Pittsburgh-based Gazzam Machine Inc. Contact him at hpgazzam@verizon.net.
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BALLSCREW BREAKTHROUGH

By William Leventon

With technology under development at Karlsruhe Institute of Technology in Germany, machining firms soon may be able to improve the process of spotting ballscrews in danger of failing.

KIT researchers have nearly completed a system for fully automated monitoring of ballscrew drives in machine tools. The system includes a camera with a light source, which attaches to the nut of a drive. As the nut moves on a spindle, the camera photographs each spindle section. These images are evaluated by an artificial intelligence algorithm capable of determining whether they show signs of wear that can lead to ballscrew failure.

Using machine-learning methods, the AI algorithm was trained with thousands of images to distinguish between spindles with and without defects. When training the algorithm, KIT reports that the research team took into account “all conceivable forms of visible (ballscrew) degeneration.” As a result, the software system can tell whether discoloration shown in ballscrew images is simply dirt or harmful pitting, according to the institute, which added that its researchers have substantiated that claim by testing the system with new ballscrew images that the system never had seen.

At present, people interested in monitoring the status of ballscrew drives in machines have two choices: measuring the motor current or the acoustics of the devices, said Tobias Schlagenhauf, a research associate who helped develop KIT’s system. He said when current or sound exceeds a specified threshold, that indicates that a ballscrew is worn. But he pointed out that both monitoring methods have significant downsides. When measuring motor current, “you can see something only when the component is very worn” and virtually at the end of its life, he said.
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As for the acoustic option, Schlagenhauf said, “it’s very hard for a user to find small defects in this signal. Finding small defects is very important because they indicate that the component will fail in the near future.”

He said the automatic KIT system is much better at finding small defects than acoustic- or motor current-based systems.

“The image data is easy to interpret because you can actually see what happens on the surface” of a ballscrew, Schlagenhauf said. “When you see something in an image, you can label this image and give the image and label to the machine-learning model. The model is trained using a large number of these image and label pairs, and it learns what a defect looks like.”

If evaluation of image data shows that action is needed, KIT’s system automatically informs a user. He said there are different options for handling information from the system. One is to supplement the system with its own computer, which would eliminate implementation difficulties involved in hooking it up to a programmable logic controller or other external hardware devices. The computer, he said, would allow users to do whatever they want with information from the system — for example, to display information or use it in their manufacturing execution or enterprise resource planning systems.

In developing its system, Schlagenhauf said KIT’s primary objective is to further research efforts aimed at understanding wear-related defects in the surfaces of ballscrews and other machine tool components. Secondarily, the institute would like to commercialize the technology in some form. At this point, however, it’s not entirely clear how companies
will get access to the technology upon completion of development work, which he believes is about a year away. As of now, the system’s machine-learning model is based on data from ballscrew drives that come from only two or three suppliers. So one item on the development team’s to-do list is to see how the model works with other ballscrew drives. Another task is to speed up surface evaluation.

“This depends on the size of the ballscrew drive, and we are not as fast as we would like,” Schlagenhauf said. “We have to work on the speed of the system so we can have real-time detection of surface defects.”

In addition to artificial intelligence, the system for monitoring ballscrew wear includes a camera and light source attached to the nut of a drive.
CHIP CONTROL WHILE TURNING

By Brandt Taylor

Some turning operations produce long, stringy chips that gum up the works. Chips that wrap around a workpiece or chuck create safety and productivity issues. Chipbreaker geometry must be tailored to a cutting operation to work well. The insert nose radius, rake angle, chipbreaker form, cutting speed and feed, and coolant flow all should be considered for successful chip control when cutting metal. Chipbreakers are useless for turning nylon and other plastics. The photograph shows a light cut being made on 304 stainless steel with a chipbreaker insert. The long chip is a problem.

Machinists can use software to get manageable chips every time by generating predictable, repeatable chip lengths. Peck drilling is a way to form reasonably sized chips when drilling. The technique used here is to peck while turning. But instead of retracting the tool parallel to the feed direction, the tool retracts at 45° so the chip is sure to break and the cutting edge does not oscillate.

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A light cut is made on 304 stainless steel with a chipbreaker insert, and the long chip is a problem.

Let's demonstrate with a G code program snippet that turns an OD and breaks a chip once per revolution. Program parameters can be adjusted to change chip size. This is generic Fanuc code. Various controls have different syntax, but program flow and commands are the same. This program uses variables across the finish surface.

---

**about the author**

Brandt Taylor is owner of Berlin, Massachusetts-based Taylor Engineering, a machine shop and manufacturer of lathe chuck jaws. He can be reached at 978-838-2979. For more information about the chuck jaws, visit www.stopjaws.com.
in a loop that repeats a cut-and-retract cycle.

Program flow. The program feeds to the beginning of the loop, N40. Then the program moves incrementally in the Z dimension by adding #2 to the previous value of #1. The program next feeds to the new #1 Z dimension. When the tool reaches Z #1, the tool retracts at 45° from the work in N70, then moves back to the work behind Z #1 in N80. The program now returns to WHILE. If the WHILE condition is true, the process repeats. If WHILE is false, the program goes to END1. Then blocks N90 and N100 clean the end of the cut. N110 retracts the tool, and the program can go on from there. Since the feed rate equals #2, one chip will be broken per revolution. With the 25 mm (0.98") cut dia., the chip length will be about 75 mm (2.95").

Here's a tip for using this type of process. When cutting metal on a lathe, the metal is compressed as it is cut, so chip length will be less than the length of the cut. A heavier cut means more compression and a shorter chip.

At top is a chip produced without using the peck technique. Below that are peck-produced chips.
Cut an OD surface
25 mm dia. × 50 mm (1.97") long
(Variables set here.)
#1 = 0.0 (Z start)
#2 = -0.3
(Z incremental cut length)
#3 = -50.0
(absolute Z position at end of cut)
N10 G50 S2000 G21 T0100
N20 G96 G21 S65 M03
N30 G0 X25.0 Z3.0 T0101
(rapid to X dimension with Z 3 mm
(0.19") from the work)
N40 G1 Z0.0 F0.3
(feed to start position
of loop, #1 = 0.0)
WHILE [#1 GT #3] DO1
N50 #1 = #1 + #2
(incremental Z dimension)
IF [#1 LT #3] TH #1 = #3
(ensures no over-cut
of Z dimension)
N60 G1 Z #1
(cut to incremental Z)
N70 G0 U1.0 W0.5
(retract tool 45° from work,
incremental)
N80 U-1.0 W-0.3
(move tool back to cutting
diameter; see note)
END1 (end of loop)
N90 G1 Z #1
(feed to finish Z dimension)
N100 G04 P80
(dwell to clean diameter)
N110 G0 U5.0 W2.5
(retract tool)
Continue program.
Please note: The Z move in block
N80 is less than the Z move in N70
to ensure a good surface finish.
This program will take about twice
as long to run as one with a
continuous Z motion, but this
will produce manageable chips.
Parameters can be adjusted to
change the run time versus the
length of chips.

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Dear Doc: We ID-grind steel bearing rings with a CBN wheel running at 8,500 rpm and a workpiece running at 120 rpm. We get about 70 chatter marks around the inner circumference of the ring. I’m trying to figure out if the chatter is coming from an untrue or imbalanced wheel or just basic, self-excited chatter. Is my thinking right on this? And is there a way to tell?

The Doc replies: Your thinking is right, and there’s a simple test to see where the chatter is coming from. First, something is happening at a frequency of 140 chatters per second, and we have to figure out what that “something” is. [Chatter frequency in Hz = number of chatter marks per workpiece revolution × workpiece rpm / 60 = 70 × 120 / 60 = 140.]

Chatter has many possible sources, but let’s start with the two most likely: 1) an out-of-balance or out-of-true wheel or 2) self-excited chatter — that is, the wheel/spindle bouncing up and down at its natural frequency. An out-of-balance or out-of-true wheel chatters at the wheel rpm, so 8,500 rpm = 142 revolutions per second. If one of those natural frequencies is about 140 Hz and the workpiece is running at 120 rpm, that will give around 70 chatters on the workpiece. [Number of chatter marks per workpiece revolution = chatter frequency in Hz × 60 / workpiece rpm, or 140 × 60 / 120 = 70.]

Since your wheel rpm and potential natural frequency are very close, how can we know if the chatter is coming from an out-of-balance/out-of-true wheel or the self-excited natural frequency? Simply slow down the wheel rpm and see if the chatter marks become farther apart (with fewer chatters per revolution). If they do, that points toward out-of-balance or out-of-true chatter. If they stay the same, that points toward self-excited chatter.

Why is that? With self-excited chatter, the wheel/spindle (or workpiece/toolholder) likes to bounce up and down at its natural frequency, and that’s independent of wheel speed. If the spindle likes to bounce up and down at 140 bounces per second, the spindle will do that at all rpm: 8,500 rpm, 7,500 rpm, 9,500 rpm, etc.

But if it’s out-of-balance or out-of-true chatter, slowing down the wheel rpm will give a lower chatter frequency and hence a bigger distance between chatter marks. (7,500 rpm = 125 revolutions per second, which now gives 62.5 chatters per revolution instead of 70.) [125 × 60 / 120 = 62.5.]

That’s a quick test to point you in the right direction of the cause of chatter. Maybe you immediately can pinpoint it, or maybe you’ll need a vibrations expert with multiple accelerometers and four days of complex computer simulation. That’s because chatter is notoriously complex. Frederick Winslow Taylor (1856-1915), the godfather of production engineering, said in 1906, “Chatter is the most obscure and delicate of all problems facing the machinist.” It’s still true today. Chatter is tough.

CTE

A shop seeks answers about inner circumference chatter marks on bearing rings.

What about the author

Jeffrey Badger, Ph.D., is an independent grinding consultant. Once COVID-19 is over, he’ll resume his three-day High Intensity Grinding Course. For more information, visit www.TheGrindingDoc.com.
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SI-derived units of measurement are defined algebraically in terms of base units. There are 22 SI-derived units. Units of measurement related to geometry, lighting, radiation and chemistry are not included in this series.

On Oct. 20, 1960, the 11th meeting of the General Conference on Weights and Measures, also known as CGPM, adopted the hertz as a unit of frequency, replacing the previous name for the unit, cycles per second. Hertz replaced cycles per second in common use by 1970. Expression of the hertz in terms of SI base units is \( \frac{1}{\text{second}} \) or \( \text{s}^{-1} \).

Heinrich Hertz (1857-1894) was a German physicist. He found that electrical conductors reflect waves and concave reflectors can focus them. These waves, originally called Hertzian waves and now known merely as waves, come in the form of both light and radio waves.

The unit of hertz bears his name. Austrian physicist Hermann von Helmholtz said, “One should emphasize the extraordinary import of Hertz’s discoveries in relation to our whole concept of nature.”

On Oct. 21, 1948, the ninth CGPM adopted the newton as a unit of force. A force of 1 N accelerates a mass of 1 kg at a rate of 1 m per second per second (\( \text{m/s}^2 \)). The mathematical expression of the newton is \( \text{N} = \text{kg} \times \text{m/s}^2 \). Expression of the newton in terms of SI base units is...
m × kg × s⁻².

Sir Isaac Newton (1643-1727) was an English mathematician, physicist, astronomer and theologian. His laws of motion and universal gravitation are the foundation for predicting a wide variety of scientific and engineering situations, especially the motion of celestial bodies.

His calculus became vitally important to the development of future scientific theories. He unified many of the physical facts that had been discovered earlier into a satisfying system of laws. For this reason, he is considered one of the greatest scientists, and the unit of newton bears his name.

On Oct. 8, 1971, the 14th CGPM adopted the pascal as a unit of pressure and stress. The mathematical expression of the pascal is \( \text{Pa} = \frac{\text{N}}{\text{m}^2} \). Expression of the pascal in terms of SI base units is \( \text{m} \times \text{kg} \times \text{s}^{-2} / \text{m}^2 = \text{m}^{-1} \times \text{kg} \times \text{s}^{-2} \). Expression of the pascal in terms of SI-derived and base units is \( \text{N} \times \text{m}^{-2} \).

Blaise Pascal (1623-1662) was a French mathematician, physicist and philosopher who made significant contributions to the study of fluids and laid the foundation for hydrostatics and hydrodynamics. The unit of pascal is named in his honor.

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**about the author**

When a workpiece material is relatively easy to machine and a wide range of parts are made of it, a large number of part manufacturers will machine it. As a result, shops must achieve a high level of productivity to remain competitive, and that’s certainly the case with aluminum alloys.

“For the customer, it’s all about how many cubic inches of material they remove per minute,” said Mike MacArthur, vice president of engineering for RobbJack Corp., Lincoln, California. “The more chips they get out as fast as possible, the more money they are going to make.”

Selecting the appropriate cutting tool, such as an endmill, for an aluminum application requires optimizing the tool’s substrate, geometric features and coating, if one is deposited.

“It comes down to tailoring a tool to a specific part and getting the most out of it that you can,” said Mitchell Parker, process improvement specialist for LMT Onsrud LP, Waukegan, Illinois. “You just have to have the right combination.”

“You think, ‘It is aluminum, and anything can cut it,’ so you can use any tool in the drawer,” he added. “To stay competitive, there are factors in making that high-performance tool that will get the material removal rates up.”

One cutter doesn’t fit all aluminum machining needs, so end users must

Give and Take

Effectively milling aluminum requires balancing all elements of a cutting tool.

By Alan Richter

A three-flute tool finishes an aluminum part.
work with toolmakers that have offerings across the spectrum.

“Because there are such a high variety of parts that are made of aluminum, you have to have a high variety of tools to serve the market,” said Alyssa Walther, automotive specialist for Irving, Texas-based OSG USA Inc., who’s based in Bensenville, Illinois.

Material Matters
A plethora of aluminum alloys are available, but the two most common are 6061-T6 and 7075, which MacArthur said is used usually to make aircraft components.

“Give and Take”

“The big player is the aerospace market,” he said. Walther concurred that 6061 is a popular choice.

“It is one of the material grades that we keep around our R&D facility for testing,” she said. In addition to the aerospace industry, Kyle Matsumoto, automotive specialist for OSG USA, noted that the industry he covers is a major consumer of aluminum, with a focus on high-volume production.

“The big difference between automotive and aerospace is the size of the parts,” he said, “such as machining huge wings.”

Those types of large aircraft parts previously were made of potentially dozens of components that were riveted, bolted or otherwise mechanically attached to each other but are now produced as monolithic structures, MacArthur said. To produce them, aircraft manufacturers sometimes turn 98% or 99% of a workpiece into chips while removing 32 kg (71 lbs.) or more of aluminum per minute.

As a result, cutting tool manu-

‘It comes down to tailoring a tool to a specific part and getting the most out of it that you can.’

about the author
Alan Richter is editor-at-large of CTE. Contact him at alanr@ctemedia.com.
Manufacturers have risen to the challenge.

“We are constantly coming out with a better version of what we did,” Walther said. “Tools that can reach a longer length and still keep chatter and vibration down are constantly evolving as the years go by.”

In addition to the various alloy compositions, aluminum comes as cast or wrought workpieces. Parker said cast can be more abrasive depending on the percentage of silicon. Therefore, cast aluminum often is machined at a slower cutting speed than wrought. LMT Onsrud recommends starting at about 244 to 305 m/min. (800 to 1,000 sfm) when cutting cast 6061 aluminum and 457 to 610 m/min. (1,500 to 2,000 sfm) when machining the wrought variety.

“Those numbers are fine and good starting points,” he said. “But at the end of the day, when you are trying
A comparison is shown of the surface finish imparted when applying (left) and not applying (right) a Mirror Edge tool.

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a low surface footage or low chip
loads unless the material or the part
dictates it. It depends on how clean
the material is in the casting.”

MacArthur agreed that 305 m/
min. is a nice starting point when
machining cast aluminum with high
silicon content but said a starting
suggestion is unnecessary when
cutting wrought aluminum.

“One on the wrought side, we are un-
limited,” he said. “We have custom-
ers taking a 1”-dia. (25 mm) tool at
33,000 rpm, which is a huge amount
of surface footage.”

A tool well suited to cut aluminum
starts with its substrate. An end
user can apply an HSS tool, but car-
bide cutters generally are needed
to boost removal rates and extend
tool life. Parker recommends a car-
bide grade with less than 10% co-
balt because it tends to stick to a
tool when exposed to a high level of
heat, resulting in built-up edge and
dulling upsharp cutting edges. But
a tool with too little cobalt might be
too hard and therefore too brittle.

While a low-cobalt-content tool
is fairly hard, to handle the high
amount of horsepower needed to
effectively cut aluminum, the tool
also must be somewhat tough.
That’s where grain size plays a role.

MacArthur said the majority of tools
with less than 10% cobalt have a
submicron grain size.

“Because aluminum is easy to
machine, you’re taking 149-kW (200-
hp) cuts and removing 70-plus lbs.
(32-plus kg) of material per min-
ute, which generates a tremendous
amount of force,” he said. “So you
want the toughest tool that’s going
to last the longest and give you the
most wear resistance.”

Playing Flutes
When milling aluminum, the num-
ber of flutes on a tool is critical. Wal-
ter said a three-flute tool is com-
mon and effective for performing
conventional roughing and semi-
finishing. Two-flute tools, however,
provide an added benefit when slotting, deep pocketing and even finishing because their design enhances chip evacuation by providing the most amount of flute space.

“If you have a longer overhang and want a really smooth finish, typically the lower number of flutes will help reduce the amount of cutting vibration because there are only two points,” she said. “You’re basically indexing the tool 180° apart, so it gives the tool a chance to calm the chatter down.”

Although a two-flute tool is more ordinary for milling aluminum, Parker said LMT Onsrud offers three-flute roughers that help lower the considerable spindle load on a machine.

However, two- or three-flute tools are not the only options when

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**Give and Take**

A selection of taps for threading aluminum is displayed.

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cutting aluminum. Walther said end users performing high-efficiency machining, which generally involves running at high feed rates and taking deeper DOCs (step-downs) and a shallow WOC, are gravitating toward tools with four to seven flutes — or more.

“It depends on what the customer’s style of machining is,” she said.

RobbJack also sees that trend.

“We have special five-flute tools that are going to be standard now that people can use to machine at thousands of inches per minute and max out their machines doing high-efficiency machining,” MacArthur said.

Nonetheless, pushing a machine to its limits doesn’t mean stressing it and shortening its life.

“We are just making sure we are utilizing all the rpm and all the horsepower that the machine has,” MacArthur said. “We have tools that reduce the amount of horsepower that’s consumed so you can remove more cubic inches per minute with the same amount of horsepower.”

Slick Surfaces

Regardless of flute count, flutes should be highly polished to help clear chips and avoid re-cutting them.

“You want the substrate to be as slick as you can get it so nothing adheres to the cutting edge,” Parker said, adding that LMT Onsrud polishes flutes before and after depositing a coating.

He noted that the more flutes a tool has, the higher the helix angle is, which increases the pull on a part. In addition, the more flutes a tool has, the larger the core is.

“The heavier the core your tool has is crucial,” Parker said. “You definitely need that because you’re applying a lot of forces on that tool by machining aluminum.”

When LMT Onsrud changes tool geometry to suit a specific application, the company bases the change on the horsepower and torque curve of a customer’s
machine, he explained. He said the toolmaker can provide specials in about six days for uncoated tools and eight days for coated ones.

MacArthur said the most common helix angle for a rougher is from 35° to 40°. That design also can be suitable for finishing, which traditionally requires a slightly higher helix angle. RobbJack, for example, offers a combination tool for hogging and finishing.

“In the old days, you would rough with a two-flute tool and finish with a three,” he said. “We have the ability now with new geometry to hog with three flutes and finish with that same tool.”

A tool doesn’t necessitate the same geometry for each flute, and a variable helix and/or variable indexing is a well-established design to help minimize vibration.

“A significant portion of the newer tools that we’re developing and bringing in have a variable-geometry component to them,” Walther said.

MacArthur said RobbJack introduced a geometry that eliminates vibration and chatter by matching tooth passing frequency to part frequency. Called Mirror Edge, it achieves stable cutting conditions by combining polished flutes, various corner radii, through-coolant capability and chipbreakers. The geometry also eradicates witness marks and staircase-shaped grooves when, for example, deep pocketing and finishing deep walls, according to the company.

However, RobbJack reports that spring passes, which are cuts taken on a wall a second time or more that follow the same toolpath, might be needed to improve finish and
A roughing tool for nonferrous applications is presented.

deflection. Company test results show that up to four spring passes can be taken with specific tools without any negative effects.

"Normally, we do not recommend doing that, and we have tools and geometry to eliminate that," Mac Arthur said. "It normally reduces tool life and lengthens cycle time. However, when the tool is sticking out and contacting the entire wall at a 5-1 length-to-diameter ratio, the tool has more flex. So a spring pass is necessary to get rid of flexing and taper in the wall."

A Lubricious Layer

To help prevent BUE and extend tool life, Matsumoto said OSG USA can deposit a diamondlike carbon coating on tools for aluminum applications.

"We are trying to reduce the friction so we can avoid chip welding on the tools," he said.
The coefficient of friction for OSG USA’s DLC coating is approximately 0.1.

Tools that cut aluminum commonly are uncoated. In those cases, Matsumoto recommends much polishing of tool surfaces to combat BUE.

MacArthur estimates that about 30% of RobbJack’s customers order tools with a DLC coating for machining aluminum while the rest choose uncoated tools.

“If you have gummy aluminums, coatings tend to be used more because they add lubricity,” he said. “Most of our customers are using the DLC coating for roughing operations, where they want to get more minutes or hours out of the tool.”

MacArthur said one disadvantage of a coating, even one only 2 μm to 3 μm (0.00008” to 0.00012”) thick, is that it adds a small hone to a theoretical upsharp edge. “If your parts are ultrasensitive
to having the most razor-sharp edge,” he said, “then the uncoated is a hair sharper.”

Applying coolant also helps reduce friction, resist heat and minimize microfracturing of a tool, Parker said. However, external coolant may not penetrate all necessary part features, such as in a deep pocket if a tool is against a wall. When possible, he recommends through-coolant tools to avoid re-cutting chips and putting unnecessary heat into a part.

To further lessen heat going into a part and tool and instead send heat into chips, end users should examine their machining strategies. He said one that aids with maintaining a constant chip load is trochoidal milling, which is circular milling that includes simultaneous forward movements.

“I know a lot of people are not using radial chip thinning, so they are underutilizing the tool,” Parker said. “More times than not, they are rubbing and not producing the chip thickness that’s desired for a specific radial depth of cut.”

When all elements correctly come together, end users cutting aluminum would be wise to have adequate hearing protection.

“We even have a customer that is cutting so much aluminum that they have cut holes in a wall of the machine,” MacArthur said, adding that the wall was replaced but not the machine. “It sounds like a machine gun going off when they’re cutting aluminum.”
Machine shops don’t have to be experts with fiber laser cutting technology to know that if they can cut a 6.35 mm (0.25”) plate with a 4-kW laser, they can cut faster with an 8-kW laser power source, let alone a 12-kW or 15-kW fiber laser cutting machine.

The main benefit of high-powered fiber laser technology is decreased process time for laser cutting. That’s often why a shop buys a high-powered laser cutting machine to replace two or even three old lasers. Parts can come off a laser bed more quickly and, accordingly, cheaply than before. But those are not the only perks.

“Pulsed fiber lasers offer numerous advantages compared with traditional fabrication methods, such as mechanical cutting, stamping and electrical discharge machining,” said Thomas Schreiner, product line manager for Coherent Munich GmbH & Co. KG, Gilching, Germany. (Coherent Inc. is in Santa Clara, California.) “The laser can be extremely spatially selective. It can be focused to a spot diameter much smaller than the width of a mechanical blade or saw, enabling the creation of finer details with greater precision.”
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He said a fiber laser typically produces a high-quality edge that requires no post-processing, reducing overall costs. Also, unlike with a drill or an EDM tool, non-contact laser processing involves no tool wear, so consistent, uniform results are delivered.

Lasers in Use

Schreiner gave an example of an application that illustrates the advantages of laser cutters. Bone drill bits, such as craniotomes, now are made routinely by laser cutting. These stainless steel devices have small, sharp edges. The use of pulsed fiber laser cutting avoids heating the bulk of the material, virtually eliminating thermal transformation, which otherwise could render these edges prone to break off. Also, the correct function of the drill depends on the precise geometry of various features — like the cutting edge, rake face and flank face — so the superior spatial accuracy of laser cutting is ideal for creating these instruments.

In terms of the laser technology, Coherent offers a comprehensive range of lasers with pulse widths from milliseconds to femtoseconds, output power from tens of watts to multikilowatts and wavelengths from deep ultraviolet to midinfrared. For medical devices, many applications are well served by near infrared lasers in the tens-of-watts power range with adjustable pulse widths, such as the fiber laser technology in Coherent’s StarFiber 100-600 fiber laser machine.

Common Composites

Composites are structures in which two or more materials combine to produce a material whose properties would not be attainable by conventional means. An example is carbon fiber-reinforced polymer, which is constructed by two materials — carbon fiber and polymer matrix — that have significantly different properties.

Ronald Schaeffer, CEO of HH Photonics, New Ipswich, New Hampshire, said numerous laser job shops are familiar with the challenges of machining FR-4,
which is glass-reinforced epoxy laminate material. An overwhelming proportion of the composite dielectric material used in the interconnect industry remains FR-4, though a lot of other materials, including CFRP, are used extensively in the aerospace industry. CFRP is finding its way into a host of new applications and is amenable to laser processing, cutting, drilling and structuring.

He is former CEO of a laser materials processing company, Pelham, New Hampshire-based PhotoMachining Inc., which has an array of laser tools ranging in wavelength from 248 nm in UV to 10 µ (0.0004”) CO₂ in infrared and with pulse lengths ranging from milliseconds to femtoseconds. This includes fiber lasers that operate in infrared with pulse lengths in the hundreds of nanoseconds.

Schaeffer said how these laser tools are used depends on the application and the power of a laser. High-energy lasers can “punch” through many materials in one pulse, which effects faster processing but results in losing some control. Lower-energy beams can be rapidly multipassed, which usually results in better cut quality and smaller feature sizes — if a small kerf is used — but at the sacrifice of processing speed. To enhance cut cleanliness, laser contract manufacturers like PhotoMachining typically design laser machines with the smallest usable kerf.

“If we squeeze that energy per pulse down into a

**about the author**

Yesenia Duran is a Chicago-based freelance journalist who covers cutting tools and technology. She can be reached at sennyx@gmail.com.
very small spot and keep the pulse length as short as possible,” he said, “it results in high peak power intensity, which is the key to clean processing.”

PhotoMachining uses a Lumera UV laser with a 12-picosecond pulse and 20-W to 100-W Q-switched fiber lasers with pulses of 100 nanoseconds and shorter for micromachining composites. Even so, PhotoMachining often laser-machines composites in multiple passes to allow heat to dissipate between them, Schaeffer said. He said cutting a feature, such as a hole, in a single pass is quicker, but the quality isn’t as high.

“The ability to tailor properties, combined with the inherent low density of the composite and its relative ease of fabrication, makes this material an extremely attractive alternative for many different industrial sectors but primarily the aerospace sector,” said Mohammed Naeem, director of business development and special projects at Prima Power Laserdyne LLC, Brooklyn Park, Minnesota.

Delamination, fiber pulling out, matrix chipping, heat damage and tool wear generally represent the main concerns when machining composites. These materials require processing like cutting, drilling and milling, typically using traditional machine tools.

Laser Versus Water

Aerospace companies recently have been investing in waterjet technology for cutting CFRP.
“Waterjet can give a high-quality cut,” Naeem said, “but this has associated problems of causing delamination and requires a pilot hole to be drilled mechanically if the cutting process starts anywhere other than at the edge of the sheet.”

“Waterjet cutting is a subtractive manufacturing technique, but it uses pressurized water focused in a very small point to cut the material,” said Alexei Markevitch, market development manager at IPG Photonics Corp., Oxford, Massachusetts.

The pressure can be as high as 27,216 kg per square inch (60,000 psi). Water may be mixed with an abrasive, such as garnet, which increases cutting possibilities by allowing more materials or closer tolerances.

Waterjet cutting is ideal for stone, ceramics and thicker metals, which are more difficult to process by laser cutting or other methods. Unlike other material removal processes, waterjet systems can cut extremely hard, reflective and nonconductive materials, making waterjet an efficient, productive method.

Composites machine differently from metals and therefore can be challenging to cut. Although shops have applied traditional cutting techniques...
tools and alternatives like waterjetting to cut composites, interest in using lasers is growing for some applications.

Lasers cut a wide range of materials: all plastics, woods and metals, excluding highly reflective metals. Lasers also process ceramics, sapphire, silicon, glass, diamond, polymers, epoxy and composites but often require different wavelengths or modes of operation, Markevitch said.

“For example, (quasi-continuous wave) 1 µ (0.00004”) lasers are versatile and can cut both metals and many nonmetals,” he said. “There is a specialized laser type for virtually any cutting requirement while the same waterjet can easily switch from paper to metal to rubber. Also, CO₂ gas lasers operating at 10 µ wavelength give versatility similar to waterjet, capable of cutting a wide range of metals and nonmetals.”

Ready for Industry 4.0 and the industrial internet of things, the ExactCut is a fully self-contained laser cutting system for medical devices.
Laser cutting is faster and more energy efficient than plasma cutting for thin or medium-thickness sheet metal, most commonly steel or aluminum. Laser cutting generally has not been possible for thicker stock, but today’s higher-wattage machines — 7-kW and up — are approaching the capabilities of plasma cutting.

Importantly, fiber laser technology effectively eliminates bend mirrors and the need for beam adjustment and alignment, which improves consistency.

The optimal thickness for cutting with a waterjet machine is between 10.2 mm (0.4”) and 50.8 mm (2”) while for a laser machine it is 3 mm (0.1”) and 10.2 mm.

Markevitch said laser cutting is much more precise than waterjet cutting.

“The minimum size of the cutting slit is 0.006” (0.152 mm) for laser cutting and 0.02” (0.51 mm) for waterjet,” he said. “As for their processing tolerance, it is of approximately 0.002” (0.051 mm) for laser cutting and 0.008” (0.203 mm) for waterjet cutting.”

**Danger of Delamination**

Each technique poses its own problems regarding part integrity. Laser and waterjet machines both can slightly damage material during manufacturing.

Laser cutting can cause burn marks on material and make the cut sides dark. In some cases, the marks may be removed by cleaning.
What Wattage

How powerful of a fiber laser does a shop need? A company should look at the thickness range that makes up 80% of shop work. If work is really thin gauge, a 15-kW laser likely is not needed.

Here are general rules for cutting common metals, such as steel, stainless steel or aluminum with nitrogen:
- Up to 9 gauge — 6-kW to 8-kW
- 6.35 mm (0.25") to 19.05 mm (0.75") — 8-kW to 10-kW
- Over 19.05 mm — 8-kW to 15-kW

Keep in mind that a shop with a high-powered machine can produce more parts per hour and part cost plummets as power goes up. But this occurs only if a laser cutting machine is quick enough to maximize the power.

Operating costs probably will rise as the power level of a fiber laser cutting machine goes up. Doubling the power generally increases laser operating costs by 20% to 30%. It’s very important for a fiber laser to operate at peak efficiency so part cycle time can be decreased to offset higher operating costs. By decreasing cycle time, a shop can reduce the impact of variable and fixed costs and increase profitability. — Yesenia Duran

Fiber on Fiber

While waterjet cutting doesn’t require heat, it applies very high forces to material. This might result in difficulties for small parts, which could become deformed or impossible to cut.

Laser cutting involves low risk, little waste and not much cleanup. But with some materials, produced dust and smoke can be slightly toxic, so proper ventilation is essential. Noise pollution also is low with laser cutting, and a machine doesn’t need much cleaning, though thermal stress can occur in heat-affected zones.

Waterjet cutting involves more risk, much noise pollution and more cleanup. Also, a cutting area becomes quite messy, with large quantities of cutting waste caused by mixing water and abrasives. Heat-affected zone charring, delamination and epoxy recession

It’s easy to say your tooling solves problems.
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due to intense thermal damage have been major obstacles for industrial applications of laser machining composites, Naeem said.

Prima Power Laserdyne has used fiber lasers to machine CFRP. He said the big advantage of a fiber laser is its high-quality beam, which results in a very small focal point, allowing composite material to be processed with minimal thermal damage to the matrix.

Surface texturing composites is a viable replacement for mechanical abrading, enabling better control over the final structured surface. This ability to machine on a microscale could create a role for fiber lasers in the aerospace industry as a new tool for laser milling fine structures involving CFRP.

Naeem said it is possible to use the new generation of fiber lasers for both the macroapplication of laser cutting and the microapplication of laser surface texturing.

“The cut-edge quality compared with mechanical cutting is superior, though surface damage may remain an issue,” he said. “Work is in progress to reduce this damage further and increase the cutting speed.”

Who Needs It?
Not all shops need a high-powered laser, particularly if they don’t have enough work to load their current laser cutting machine. If laser cutting work is not expected to grow and consumes just half a workshift, then paying for a more powerful laser to reduce the workload to a quarter of a shift likely won’t deliver a good return on investment.

But shops that have maximized their laser cutting capacity and are looking to add a shift should consider a high-powered laser. This is especially true if they use old laser technology. At a time when shops struggle to find reliable, experienced operators, investing in a fast, efficient fiber laser also may reduce the number of needed laser operators.
Tool manufacturers can specify special coating colors to distinguish products.
Coated cutting tools, such as drills, mills, inserts, threads, reamers, broaches and hobs, tolerate significantly higher cutting speeds and feeds, reducing machining time and costs. Outstanding wear resistance also substantially extends tool life and lowers the cost per piece.

“Anytime that you can make the tool last longer, it’s a great benefit,” said Nikhil Sheth, CEO of Santa Fe Springs, California-based Precision Cutting Tools LLC, a manufacturer of cobalt and carbide tools. “Carbide isn’t cheap, so for maybe 10% of the cost of the tool, you’re adding upward of 50% to the life to the tool.”

He observes that the use of coatings in general has increased as coating technologies simultaneously have continued to improve.

“All the new alloys like Inconel and titanium are superlight, but they’re getting harder and harder to cut,” Sheth said. “So the whole coating industry is getting much more niche, more high-tech while at the same time it’s becoming more accessible for manufacturers to get that technology in-house.”

In the past, cutting tool manufacturers often shipped their tools to shops specializing in coatings. But with improvements, such as automation, and increased use of specialized coatings, more toolmakers are finding that bringing coating capabilities in-house makes sense.

Lower Barrier to Entry
For many tool manufacturers,
Coating is not their main business but an important part of it. Sheth said entering the coating game is much cheaper these days.

“As a previous job coater, most of the large manufacturers that were sending me business have gone ahead and made the investment themselves,” he said. “I think they realize that if they already spend a certain amount of dollars a month on coatings, they’d probably spend the same amount with half the headaches just keeping it in-house.”

Sheth said sending out tools for coating can complicate the manufacturing process.

“Logistically, it can become a nightmare because you have a long turnaround time and you still might lose a package that has $2,000 or $3,000 worth of tools in it,” he said. “Then you have to package it extra carefully to prevent breakage. And when you get the tools back, you still have to inspect them to make sure they’re OK.”

Different Coatings for Different Applications

Christopher Halter, manager of equipment sales and service at Oerlikon Balzers Coating USA Inc., Schaumburg, Illinois, said typical coatings include TiN, TiC, TiCN, MT-TiCN, TiCNO and $\alpha/K\text{-Al}_2\text{O}_3$. Additional components and component groups extend further flexibility to coating designs, such as TiAlN, TiBN, TiB$_2$, CrCx and Cr$_2$O$_3$.

Each coating shop, whether in-house or a provider, develops its own coating recipes. When considering bringing coating in-house, manufacturers may want to focus on four or five recipes that will work best for customers. Specific properties can be adjusted for the different applications in which a tool will be used.

“As an example, for drilling, you need a low thermal conductivity, you need hot hardness, you need oxidation resistance, you need chip evacuation, and you need to reduce torque,” said René Scheibe, COO of Paris-based coating equipment maker Partner Development Industry International, which does business as PD2i and has a U.S. location in Fox River Grove, Illinois. “A carbide tool itself cannot supply all these functions. But through a dedicated coating, you can apply these characteristics to your tool.”

Coatings also may add an attractive, shiny appearance and offer options for differentiation and identification.

“Some customers ask us for a

about the author

Holly B. Martin is a science writer and technical copywriter based in Winchester, Virginia. For more information, visit www.hollybmartin.com.
standard coating like aluminum chromium nitride, but they want a dedicated color, such as purple or green, for marketing purposes,” said Dirk Haack, CEO of PD2i Europe GmbH, Düren, Germany. “It should look different than the coatings of other companies even if the performance is the same.”

**Chemical and Physical Vapor Deposition**

While an array of coating technologies has been developed, two of the most common types in the cutting tool industry are chemical vapor deposition and physical vapor deposition.

For the CVD process, reactant gases are piped into a reactor, or furnace, at a specific temperature and pressure. Inside the reactor, the gases come into contact with a heated tool substrate and plate out as a solid layer coating the surface.

PVD coatings are created using one of two techniques. Both start with a high-purity, solid-metal target, such as titanium, chromium or aluminum, which then is evaporated by either heat (arc evaporation) or bombardment with ions (sputtering). At the same time, a reactive gas — for instance, nitrogen or a gas containing carbon — is added to the coating chamber. Ions in the gas form compounds with the metal ions vaporized from the target. These compounds then are deposited on tools or components as
Coatings Covered

A thin, highly adherent coating. “PVD is a line-of-sight process, so the surface you want to coat needs to be in line with the evaporator to create a uniform coating,” Halter said. “So if we’re talking about shank-type cutting tools, you need to rotate them in the chamber to get a consistent coating thickness distribution.”

Scheibe believes that 80% to 85% of coatings applied to cutting tools today are PVD coatings. “With PVD, you can play with the hardness, the coefficient of friction, the temperature and the material composition,” he said. “You have all these different materials, which completely change the performance of the coating for many different applications.”

Benefits of In-House Coating

Coating tools in-house provides clear advantages, starting with the difference in costs compared with coating at an outside shop. Coating consumes relatively small amounts of electricity, gas and metal from the target.

“Let’s say it costs $2 to have an endmill coated at a coating shop,” Haack said. “But if you have your own machine, coating the same tool would cost about 20 cents, not including the capex and labor costs.”

Other benefits of bringing coating services in-house are flexibility and simplicity. “Job coating services need to gather enough tools to fill up a batch, and they tend to run a special coating cycle maybe once a week,” Haack said. “But if you’re doing it in-house, you can control the timing yourself, so the degree of flexibility is much higher.”

“For critical industries with specific quality control needs, having the equipment in-house also can make the quality process simpler — i.e., fewer external supplier audits,” Halter said.

Limitations of In-House Coating

In addition to the initial investment in equipment, there are other considerations when bringing coating capabilities in-house. For example, a company might need to
hire and train at least one operator, as well as a supervisor to oversee coating operations. “You definitely have to dedicate personnel to it,” Sheth said, “because it takes time to clean the product, fixture the product and then un-fixture the product.” Lack of machine capacity can be another concern for shops getting into the coating business. “When you are starting up and have only one machine,” Scheibe said, “you are limited in your coating
portfolio because you can only do three to four cycles a day while a coating service can offer a much wider portfolio with many different types of coatings. You also don’t have a backup. And if the machine is down, you cannot so easily go back to a job coating center again, because their coating recipe will be different. It’s sufficient for catalog tools but not for specials."

A Complete Coating Station
A cutting tool manufacturer seeking to bring coating work in-house needs to purchase not only a coating machine but machines for cleaning and edge prepping tools, as well as finishing them after coating is applied.

"The cleaning line is super-important because there can't be any dust or oil on the tools, which is huge," Sheth said, "because you use oil to grind the tools, so you need to make sure it's completely clean. Then you need all of the accessories like the rotating planetary systems and other fixtures to load the tools into the coating machine. And to accommodate all this equipment, a shop needs to dedicate at least 1,000 sq. ft. (93 sq. m) of floor space."

He looks for a three-year return on investment from coating machines, and he believes they’re well worth the money.

"It's a daunting task to create a coating center, but some companies offer a turnkey coating facility so you don't have to go to 10 different vendors and figure it all out by yourself," Sheth said. "They have a wealth of knowledge and can help with the whole process, getting you set up and trained and help with applications."

"We find that most of our customers, after operating for one or two years, get their feet wet and get more experience," Haack said. "And as soon as they know how to do it, usually their business increases and they are ready for the next machine."

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By Christopher Tate

Anyone who earns a living at a machine shop probably has heard about centerless grinding, but it is an obscure process often only familiar in name.

The three basic types of centerless grinding are through-feed, in-feed and end-feed. In each case, the fundamental configuration of a machine is identical. The three primary components of a centerless grinder are the grinding wheel, regulating wheel and work rest, or blade.

Components of Centerless Grinding

Grinding wheels do the work as they would on other grinders. Abrasive materials are the same as with other grinding wheels, but the size and shape of centerless wheels differ from other kinds of grinding wheels. Centerless wheels most frequently are bonded with resin materials, unlike other sorts of wheels, which are vitrified. Resin bonding enhances the efficiency of centerless grinding and produces a more resilient wheel. Like a grinding wheel, a regulating wheel is made of an abrasive material but usually is bonded with rubber or some other similar substance. As the name implies, a regulating wheel regulates the speed of a part as it is rotated against a grinding wheel. A regulating wheel may be more critical to the process than a grinding wheel because a regulating wheel controls the material removal rate, surface finish and geometry.

Like a regulating wheel, a work rest might be more important than a grinding wheel. A work rest supports a part during grinding. It is easy to see in the diagram on Page 56 how the whole process would be impossible without a work rest. It most often is made of a hard material that resists the tendency of a part to pick up material from a rest. A rest commonly is capped with a carbide strip. The geometry of a rest is crucial as uneven surfaces can allow a part to flex, resulting in chatter.
poor surface finish and incorrect geometry. A work rest generally has an angled working surface, which plays a vital role in the efficiency of the process. As the angle becomes steeper, the rounding action of the process is enhanced.

These three components can be configured in several ways to allow a part to sit on the centerline of the wheels, above center or below center. Most setups place a part above center of the wheels. The angle of the work rest surface height above center and the tangency of the regulating wheel and grinding wheel to a workpiece create a unique geometric arrangement that allows the centerless process to efficiently generate round parts.

Types of Centerless Grinding

Through-feed grinding is the most popular form of centerless grinding. Through-feed grinding is performed by traversing a part from one side of the machine to the other, between the grinding wheel and regulating wheel, without stopping. Axial feed is created by dressing a regulating wheel and tipping it at an angle relative to the blade and grinding wheel, normally about 3°. This combination of factors pulls a workpiece across the work rest and between the grinding wheel and regulating wheel. Through-feed grinding is very productive. At a previous employer where we made power steering gears, we would grind 0.305 mm (0.012") from a 31.75 mm-dia. (1.25") steel bar that was 914 mm (36") long. The full process took 33 seconds, and we held the diameter to a 0.0127 mm (0.0005") tolerance and produced roundness within 0.0051 mm (0.0002").

In-feed centerless grinding, also known as plunge grinding, is conducted by placing a part on the work rest and radially feeding the part into the grinding wheel with the regulating wheel. In-feed grinding is used when a part has one portion that is larger than another. Crush form dressing imparts the desired shape into the grinding wheel. This method is used to create complex forms or generate multiple diameters at one time. In-feed grinding is efficient at generating small parts with close tolerances.

End-feed grinding is accomplished by feeding a part into a machine, much like through-feed grinding. With end-feed grinding, a part runs axially like with through-feed, but an end stop prevents the part from traversing all the way through the machine. End-feed grinding is used ordinarily to produce tapered parts.

Advantages

Centerless grinding can replace turning when parts have high length-to-diameter ratios, fine finish requirements and close tolerances. The process works well when finishing thin-walled components that are difficult to clamp. Centerless grinding can be used to rough bar stock before other machining operations so material arrives clean, round and straight. Bars for Swiss machines often are ground before use.

There are many benefits with centerless grinding, but most shops do not have enough work to support the purchase of a centerless grinder, nor do they have people with the skills needed to efficiently set it up. (A fair amount of magic goes into getting good parts from a centerless grinder.) Fortunately, many job shops specialize in centerless grinding. Recognizing centerless applications and finding a good job shop to grind parts can reduce aggravation with tough jobs, lower costs, improve margins and make a company more competitive in the market.

about the author

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An epoxy-coated floor provides a modern, clean look, but it won’t stay that way if forklifts or other forms of wheeled transportation move heavy loads over it. Lincolnshire, Illinois-based GF Machining Solutions LLC reported that it realized that effect after the machine tool builder coated a concrete floor with epoxy at a demonstration showroom. The company previously used forklifts to move milling machines, EDMs and laser cutting machines from a warehouse to the showroom.

The machine builder researched air lift systems to avoid scratching the expensive epoxy while moving machines. Based on a recommendation, AeroGo Inc. of Seattle was asked to demonstrate its air caster rigging system, which also is referred to as air skates or air dollies. For the demo, GF Machining Solutions selected a difficult-to-move machine that’s larger than what the company typically moves. The system displayed its ease of use and ability to prevent equipment from contacting the floor.

Although forklifts have rubber tires, John Massenburg, president and CEO of AeroGo, explained that forklifts tend to damage epoxy when the tires turn in a fixed position, digging even a minimal amount of dirt and grit into the epoxy and scratching the surface.

“AeroGo says its air caster system is simple and fast to implement.”

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**SOLUTION PROVIDER**
AeroGo Inc.
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www.aerogo.com

<table>
<thead>
<tr>
<th>CHALLENGE</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move machine tools over an epoxy-coated floor without damaging the epoxy.</td>
<td>Air casters that use standard plant compressed air to lift and move heavy loads.</td>
</tr>
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</table>

“The scratches are in the epoxy itself, so there’s no real way to get them out,” he said. “Scratches start, and then you get dirt embedded in the epoxy. It’s not pretty.”

**correction**

In May’s issue, the article “Fastened for flight” by Kip Hanson incorrectly identified Technical Sales Engineer Matt Baumet of Heule Tool Corp. in Loveland, Ohio, as a source. The information actually came from President Gary Brown. CTE regrets the error.
in them, and it starts not to look so good.”

Massenburg said rollers are an even less appealing option. Their steel wheels cause epoxy to flake, eventually destroying it as they directly contact a floor while carrying heavy, concentrated loads.

Although a damaged area can be stripped and epoxy can be reapplied, “the odds of the match being good enough not to tell are pretty much zero,” he said.

In addition, Massenburg said cranes were not logistically practical because they have limited reach and therefore still require a machine to be moved across a floor.

“What they’re doing is more of a rigging move,” he said about GF Machining Solutions.

Air casters, on the other hand, fit under an object to be moved and use the same basic principles that power a game of air hockey or a hovercraft but scaled to move industrial-sized machines that weigh up to 6,350 kg (14,000 lbs.), Massenburg said. Operators use standard shop compressed air to fill a flexible doughnut-shaped air bag attached to each caster. As a bag inflates, it lifts a machine by about 51 mm (2”) and forms an airtight seal with a floor. Once a bag reaches capacity, excess air is squeezed between the air bag and floor, creating a nearly frictionless film of air. At that point, the load literally is floating on a cushion of air.

He said air casters also distribute the total weight of a load over a large surface area, producing low floor loading. The net floor load with air casters usually is identical to the load generated by a person walking across a floor.

With a friction coefficient of 1 or less, air caster systems typically require as little as 0.45 kg (1 lb.) of force for every 454 kg (1,000 lbs.) of weight to be moved, or only one-tenth of the force needed to move as wheeled casters, Massenburg said.

Workers at GF Machining Solutions prepare a machine to be moved with AeroGo’s air caster rigging system.
He said moving a machine necessitates as few as two people. “None of these are fast moves,” Massenburg said, “so you just take your time and be careful.”

He said a machine can be prepared for moving in about 15 minutes. A machine generally sits on a set of legs, and areas are available underneath to insert the air casters, which are about 76 mm (3”) tall. If called for, users can place plywood cribbing on a caster to fill any gap between the caster and the machine.

Air casters also fit where forklifts cannot go. Large material-handling systems require a lot of space and open clearances for maneuvering. In a closely packed layout, this introduces the risk of damage to equipment or people if a forklift accidentally backs into anything, Massenburg said.

He said air casters are well suited for turning tightly and squeezing into snug areas. “It’s not uncommon for these machines to barely fit inside the door,” Massenburg said. Because air casters fit neatly within the footprint of a load to be moved, they can move omnidirectionally.

“I can rotate an object in its own envelope,” Massenburg said. “You can’t do that with a forklift or some other device that sticks out beyond where the load is. Even on regular concrete, the move is easier, faster and safer with air casters than it would be using rollers or any other method.”

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To reduce scrap and improve productivity, the Artis GEMDS system from Marposs Corp., Auburn Hills, Michigan, detects spindle anomalies in real time. This helps shops prevent damage to machines and avoid out-of-tolerance components. The system uses data from a noncontact eddy current sensor to monitor spindle elongation on machine tools due to temperature changes or other causes of displacement.

“During machining processes in machine tools, temperature variations occur,” said Product Manager Jorge Pena. “And in most cases, these variations are the cause of spindle growth, which leads to poor workpiece quality and damages.”

The system gives early feedback if set limits are exceeded.

“The GEMDS system uses contactless sensors to measure the variation of the distance of a specific target and then either generates alarms to stop the machine or transmits the information to the numerical control to provide a compensation,” Pena said.

The system consists of the eddy current sensor, an amplifier, a connecting cable and a monitoring module. Four different sensor signals can be monitored — one for displacement and three for temperature — sharing real-time feedback on critical variations. GEMDS has a measuring range of 550 µm (0.022”) and precision down to ±0.2 µm (0.000008”).

“The system monitors the displacement of spindle and machine parts before and during machining,” Pena said.

GEMDS functions as an intelligent stand-alone solution installed on a mounting rail in a switch cabinet. All necessary interfaces are available for easy integration into existing controls, network environments and Industry 4.0 solutions. As part of the Genior Modular product family, the system can be integrated into a Genior modular monitoring system for process monitoring purposes, creating a flexible solution to adapt to changing needs.

“The modular system design can be configured to a dedicated system or machines or added to systems as needed,” Pena said. “It is preferable for a high-precision machine process.”

He said GEMDS improves process reliability thanks to continuous monitoring of machining operations. The system helps increase productivity and workplace quality, better utilizes a machine and allows integration of tools with sensors.

Pena said although GEMDS is capable of measuring phenomena that vary slowly like thermal variation or leakage of fluid, the system also measures other phenomena, such as planarity error, misalignment and eccentricity of rotating parts.

For more information about Marposs, call 248-370-0404 or visit www.marposs.com.
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