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Modern Machine Shop

Is Just-in-Time a Thing of the Past?
Supply chain instability has forced the industry to rethink inventory pg. 30

Speeding Orthopedic Implant Launches
A streamlined process boosts development time by up to 87% pg. 56

From Swiss Bench to American Shop
How this Swiss-trained watchmaker is bringing production home pg. 80

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HOMEWORK: 7,000 Parts a Year

How a student-run CNC lab gained 30% more spindle time

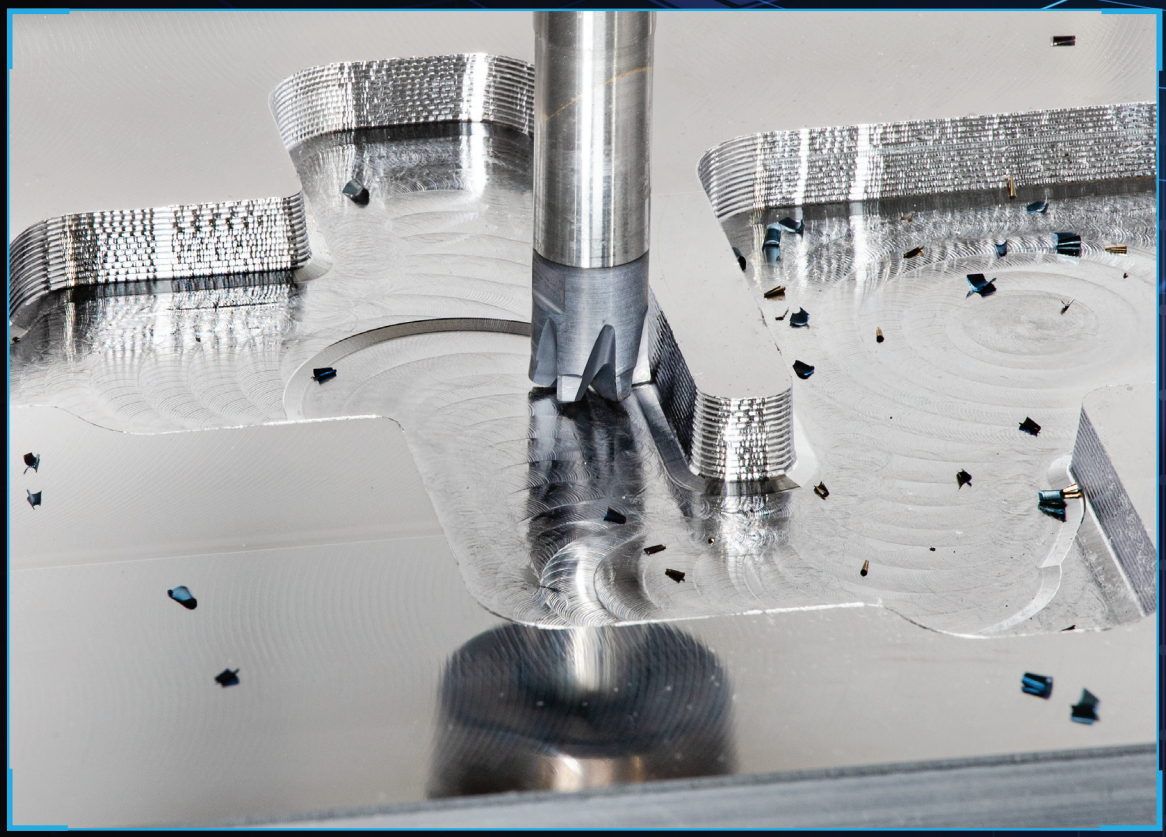
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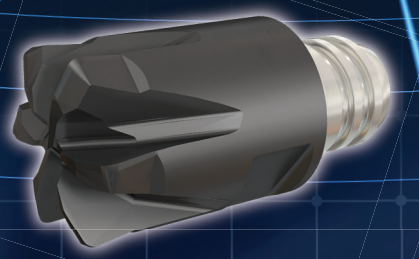
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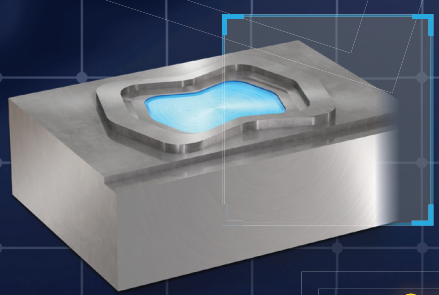
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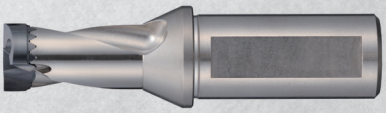
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Modern Machine Shop

FEATURES

NOVEMBER 2026
VOLUME 99
NUMBER 6



44 TOOLHOLDERS

Heat-Shrink Toolholders Help University CNC Lab Reach Full Potential

A heat-shrink toolholding system donated by Haimer is helping students make parts for aerospace and automotive competitions at Purdue University's Bechtel Innovation Design Center.

CONTRIBUTED BY CARY LEIMER, LIAM MROCZEK AND ATULRAM VUCHA

MILLING TECHNOLOGY

50



A Five-Axis Machine With The Right Stuff

A new Trimill milling machine with a five-axis head has enabled aerospace and defense shop Votaw Precision Technologies to take work it wouldn't have previously considered.

BY JULIA HIDER

SOFTWARE

56



Software and Standardization Speed Orthopedic Implant Launches

One base CAD model, one standardized shopfloor approach. These ideas enable Mach Medical to get new orthopedic implants to market as much as 87% faster.

BY JULIA HIDER

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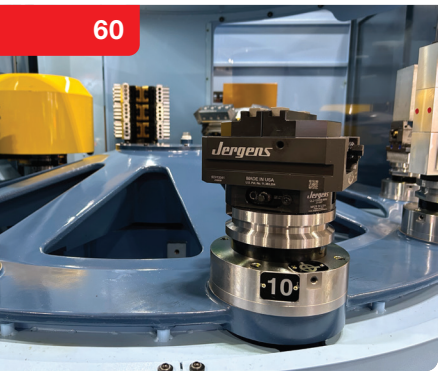
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Also in This Issue



WORKHOLDING

How to Counter Jaw Lift and Wear

Jaw lift is a natural force that pushes parts ever so slightly out of the vise. Uncontrolled, it can throw ultra-precision parts out of tolerance. Careful planning can counter its worst effects.

BY EVAN DORAN

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SPOTLIGHT: ADDITIVE MANUFACTURING

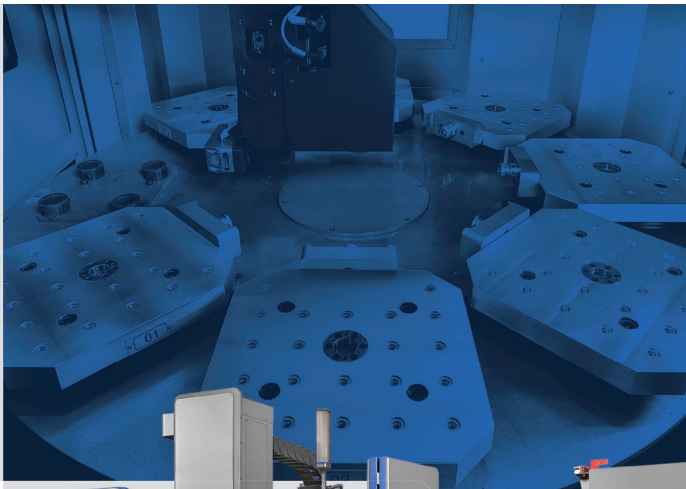




Homework: 7,000 Parts a Year
The Bechtel Innovation Design Center is a student-run makerspace at Purdue University. A new set of shrink-fit toolholders, donated by Haimer, have helped the aerospace and automotive teams who frequent the CNC lab produce the parts with deep features their teams need to succeed.

DN SOLUTIONS

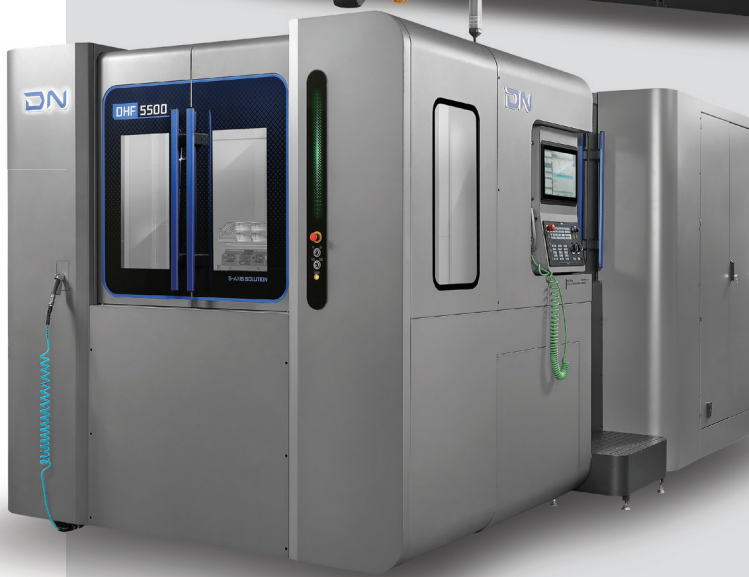
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See the Future of Automation in Action!



15 MIN.

ARTICLE | Automation Enables Just-in-Time Implant Manufacturing

On page 56, Executive Editor Julia Hider writes about how Mach Medical uses a digital thread to streamline the programming for implant variations and shorten lead times. This isn't the only area of the shop seeing improvements, however, as Hider wrote another article about the company's inventory management strategies.

READ: gbm.media/Inventory1126

15 MIN.

ARTICLE | Inside the Machine Tools Powering American Watchmaking

This month's How I Made It focuses on the manufacturing journey of Cameron Weiss, founder and CEO of the Weiss Watch Company. But how does his company machine its watches? Explore the details in our linked article.

READ: gbm.media/Watchmaking1126

12 MIN.

ARTICLE | Balancing Passion Projects With Regular Profitability

Hider, on page 50, discusses how Votaw Precision Technologies expanded its capabilities with a Trimill machine smaller than its usual machines, while keeping up its favored large-part work. For more about how to balance a shop's favored work against new markets, read Senior Associate Editor Evan Doran's discussion of 2025 Top Shop Aerotech Machining.

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EDITOR-IN-CHIEF

Would You Buy Your Own Shop?

How much capacity is enough? Who makes the cut when hiring? And what makes a shop worth buying? At Top Shops 2026, manufacturing leaders tackled these questions and shared hard-earned lessons from their own businesses.

"Boy, you ain't no machinist at all, but I can make you one."

Drew Crowe heard those words after applying for a machine shop job during the recession. He had never seen a caliper or micrometer, and he definitely hadn't interpreted G code. The front of the test looked like "the Valentine's Day massacre," Crowe joked. "It was all red."

Then he turned the page. The fractions and decimal equivalent problems were much more familiar territory. For that side of the test he drew on his practice weighing and selling drugs and aced the entire page.

Crowe, the founder of the New American Manufacturing Renaissance, used his life experience to challenge the shop owners gathered at the 2026 Top Shops Conference in Cleveland: How many capable people are being screened out because employers look at only one side of the page?

I write this just after wrapping up the conference, where the two-day program covered workforce development, automation, financial management, AI and business succession. Shop owners described investments that paid off, automation that went wrong and decisions they would approach differently today.

Lessons From the Honorees

At Precision Profiles, Matthew Lucco averages about 10 minutes for a setup. One reason is his willingness to spend $15,000 on a fixture for a $12,000 purchase order. "We take a loss on the first one. So what?" he said.

When COVID-19 cut revenue at Hill Manufacturing & Fabrication by 60%, Mike Payne chose not to lay off employees. The company prepared for the rebound by working through deferred projects and by 2021 had doubled its 2019 revenue.

At HEI Precision, owner Mark Holz and his team of roughly 10 produce 40,000 to 50,000 parts a month. He described a robotic cell that reached 12-hour unattended runs within three weeks. On the human side, Astro Machine Works HR Director Charissa Gift said the company opened its books to employees in 2007, which led to employee ownership about a decade later.

When Automation Goes Wrong

Matt Sand of Avalon Manufacturing put a number on the value of productive time: two additional spindle hours a day, over 250 days, add 500 hours per spindle annually.

Sand also described a lesson from his own shop: a robot and its software repeatedly marked a machine cycle complete even when the machine wasn't running. By morning, the system had loaded 50 pieces of raw material without producing a single part. "The goal is not automation," Sand said. "The goal is productive spindle hours."

Capacity and Process

Mike Bauer Sr. and Michael Foy of Marathon Precision explained a different approach to capacity. Bauer intends to add a machine weighing 99,543 pounds despite having no immediate work for it. He joked that he would add 437 pounds to push it over 100,000.

"Everybody worries about spindle utilization and this and that," Bauer said. "I don't, because I have extra spindles." Foy said Bauer's approach has created "a platform that can go in any direction at any time."

And then Ted Toth described a completely different kind of process improvement. After 50 years in the business, he learned that his habit of transposing numbers was associated with dyslexia. His shop responded by rewriting quality »

Methods

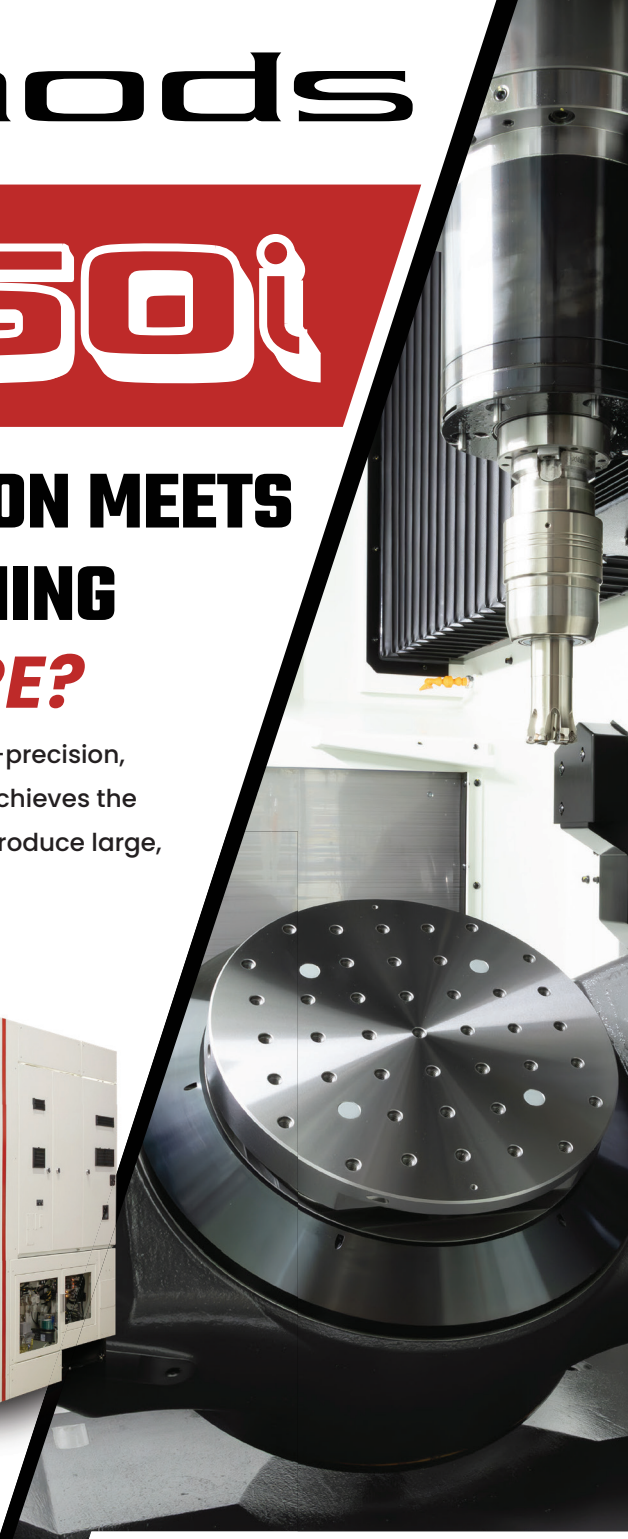
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procedures as one- and two-page flowcharts. Now every department has whiteboards, "and they're not for scheduling," Toth said. "They're for solving problems."

Other Lessons From the Sessions

David Caputo, co-founder of presenting sponsor Harmoni, said venture-backed autonomous-factory startups had attracted $2 billion in six months. Even under an optimistic scenario, he calculated, four such companies would account for just 0.4% of U.S. manufacturing value-added.

His warning: "You're not going to be replaced, but you will be outquoted."

Gardner Business Media's very own Dave Necessary presented Top Shops benchmarking data showing that top-performing shops ran machines an average of 12.75 hours per day, compared with 8.8 hours for other shops. They also generated nearly twice the sales per machine. Yet other shops won a higher percentage of quotes. Top Shops typically quote far more work.

Jayme Rahz of Midway Swiss Turn described buying machine-monitoring technology on a salesperson's ROI projections, then removing it when it didn't fix the real problem. "We automated the symptom," she said.

Elisabeth Smith, president of Acutec Precision Aerospace, on AI adoption: "You don't start with the A in AI. You start with the I."

Paul Van Metre of ProShop told a cautionary tale about a shop owner who sold his Bridgeport mill on Facebook. He had run his shop for 37 years, had to be out by the end of the month and had no buyer. He ended up selling all of his equipment for pennies on the dollar. The owner, Van Metre said, "had built a business that was completely dependent on him."

While Crowe asked owners to look at both sides of a job candidate, Michael Schroeder of Taureau Group asked them to look at their own business the way a buyer would. He explained why one shop might sell for five times EBITDA while another sells for nine times.

He then closed with a question: Would you be a buyer of your own business?



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Range vs. Resolution: The Mechanics of Digital Readout Accuracy and Inductive LVDT Probes

From LVDT linearity specs to amplifier range restrictions, selecting the right inductive probe requires more than matching dimensions. Here's what to consider before your next measurement setup.

PAUL MAILLOUX | COLUMNIST

Modern digital readouts, along with advanced electronic evaluation amplifiers and software, allow users to set display resolution independently of the analog display range. The primary advantage of this capability is that an inductive probe with a large measuring range can still be viewed at a very fine resolution. This allows operators to monitor part approach more easily and measure parts across a larger variation of sizes.

The most common misconception is that high display resolution equals high measurement accuracy. This is far from the truth.

For example, an inductive length-measuring probe (LVDT type) may have a linearity error of 3.0 µm (120 µin) near the ends of its ±2 mm (0.080 inch) measuring range. However, a high-precision electronic evaluation amplifier unit can be set to a display resolution as fine as 0.01 µm (1.0 µin). While the LVDT probe may achieve linearity errors under 0.25 µm (10 µin), it can do so only across a very short measurement range near its electrical zero (null) position, where it is most linear. Of course, inductive probe specifications vary, so make sure the selected probe is sufficient for the application.

To prevent false confidence in high-resolution readings, advanced electronic evaluation amplifiers help reduce potential error in the same way dial-type or analog amplifiers do. As a higher resolution is selected, the amount of visible measuring range is limited. These range-limiting safeguards keep the system's accuracy more in line with the readings displayed at the higher resolution.

Some electronic evaluation amplifiers have two digital ranges. When using resolution settings down to 0.1 µm (5 µin), the digital display range is basically infinite and dependent on the inductive probe's available range, typically up to ±10 mm (0.4 inch). It spans the full mechanical capability of the connected probe. When selecting ultra-fine resolutions of 0.01 µm (1.0 µin), the amplifier restricts the usable display range to ±0.20 mm / ±0.008 inch.

Limiting the range is necessary to ensure the user is aware of the type of measurement they are making. It simply makes no sense to measure at a 0.01 µm (1 µin) resolution if the standard, workpiece, instrument (readout and fixture), part and environment cannot achieve sufficient accuracy to justify the high-resolution selection.

As a general rule, set the resolution no higher than 1/40th of the total part tolerance. Common applications for general pass/fail inspection apply the 1/10th rule. However, collecting data for statistical process control (SPC) analysis often requires higher resolution to ensure enough variation to capture process variation.



Source: Mahr Inc.

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different measurement application needs. However, one thing is true: every inductive probe has its own unique qualities. So how does one find the right probe to partner with?

An inductive probe's identity is defined by its electrical signal output curve, typically characterized by an "S" shape plotting deviation error against an ideal straight line over its full measuring range. All inductive analog probes have increasing deviation, or linearity error, as the reading moves away from its electrical zero position (null). Thus, these are called zero- or center-based systems.

The "S" shape is formed when the mechanical movement of the spindle positions the core (mounted on the spindle) up and down inside a coil assembly. The coil's electrical signal is balanced at an electrical zero output when the core is precisely in the middle of the coil assembly. This is why amplifier readouts allow the raw probe signal to be displayed in special absolute modes so that the most accurate part of the probe can be set against a zero or nominal master.

This type of measurement system is called a comparative system because it compares the difference between a part and its master.

Probe ranges are set by their mechanical design, while final system resolution depends on the amplifier design, display instrumentation and mechanical hysteresis. Electronically, an analog LVDT probe's resolution is infinite and limited only by the instrumentation it is used with; mechanically, it is limited to repeatability and hysteresis characteristics.

The first step to selecting the right probe is the application itself. Part characteristics, tolerances and desired resolution are only part of the picture. Even further, don't assume probes with a shorter mechanical range have better accuracy or resolution. For instance, a miniature right-angle LVDT probe with a range of ±0.5 mm can exhibit 3.75 times higher linearity error at the ±0.5 mm point compared to a larger ±2.0 mm range probe measuring at the exact same distance.

However, compact probes can fit into tight spaces where larger-capacity models simply cannot. Ultimately, selecting the right probe and readout system always comes down to the unique demands of the specific application.

AUTHOR | Paul Mailloux
Director of Engineered Solutions, Mahr Inc.





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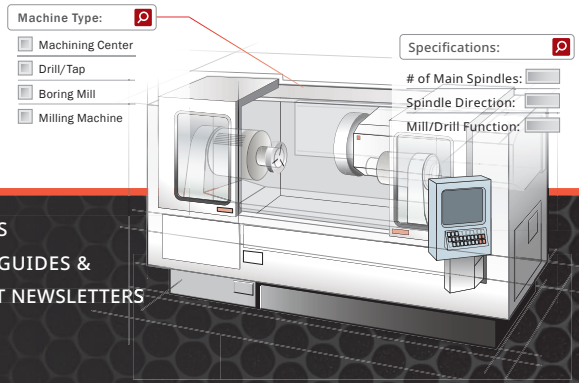
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How to Restart a CNC Program After an Unexpected Stop

Every unplanned stop forces a critical choice: recover the part, restart from a known point or scrap it. Here's how to stop making that call on the fly and build a repeatable restart process for your shop.

JOHN MILLER | COLUMNIST

READER QUESTION: *When a machine stops unexpectedly mid-cycle, our operators all handle it differently. Some will try to save any part, some scrap everything and start over. How should we build a consistent approach to restarts?*

Restarting is a decision before it is a procedure. Every time a machine stops on its own, the operator has three options: let the control put the tool back on the exact block, pick the program up from a known point, or scrap the part and start over. Most shops never decide which of those is the default, so the choice gets made at the machine by whoever is standing there, based on their confidence and how badly they want to save the part. That is where the inconsistency you're seeing comes from, and it is fixable, because the decision can be made once for the kind of work you do, rather than fresh at every alarm.

Getting the tool back to the right block is the last step, not the first. Before any of that, someone must answer whether the part can still be saved. Did it move against its locators? Did the tool break into a finished surface? Is the feature being cut still within reach of a good result? Then, whether continuing is worth the risk compared with the cost of starting over. Only after those two are settled does the question of where and how to restart matter.

The Three Restart Types

Machine-driven restart. Most modern controls have a program restart function that reads the program up to a block you choose, rebuilds the modal state, the active offsets, spindle and coolant along the way, and positions the tool at that block. This is the right tool when tool paths are long, because restarting a six-hour surfacing pass from the top throws away hours to recover a few minutes. The caution is that the control rebuilds the state it was told. If the tool was replaced and the offset changed, or the part was re-probed, the operator should confirm what the control restored matches what is in the machine.

Program-driven restart. The operator restarts from a sequence number or the top of a tool path, which is the safe start block for that tool. This is the cheapest and safest restart when tool paths are short, which is most production work. The cost is recutting what was already cut. A recut pass behaves like a spring pass, so on a finish wall or a bored hole, decide whether that leaves a good part or a scrap one rather than assuming. And don't restart into a tapped hole if there is any chance the spindle orientation changed.

Full reset. Scrap the part, reload material and run from the beginning. This gets treated as a failure and it shouldn't be. It is the only restart that returns the machine to a fully known state with no accumulated risk, and on the right parts it is the correct answer every time.

Four inputs settle which restart type to choose:

- The value already in the part, which means hours of machining, expensive material or heat treat and processing that cannot be repeated cheaply.
- The cost of raw material, which is the price of a full reset.
- Timing, meaning what a scrapped part does to delivery and what a failed rescue does to the machine schedule.
- The type of cut that was running when it stopped, because a roughing pass is forgiving and a finish pass on a critical surface usually is not.

Run those inputs against your work and a default falls out. A high-volume shop machining die castings will scrap the part almost every time. The casting is cheap, the cycle is short and »

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a minute of machine time is worth more than the part, so the rescue is never worth the risk of a second incident. A tool and die shop is the opposite. A hardened core with 40 hours of roughing in it has too much value to abandon, so that shop will always look for a way to continue, and its process is built to make that possible. Neither is wrong. The mistake is not having a default.

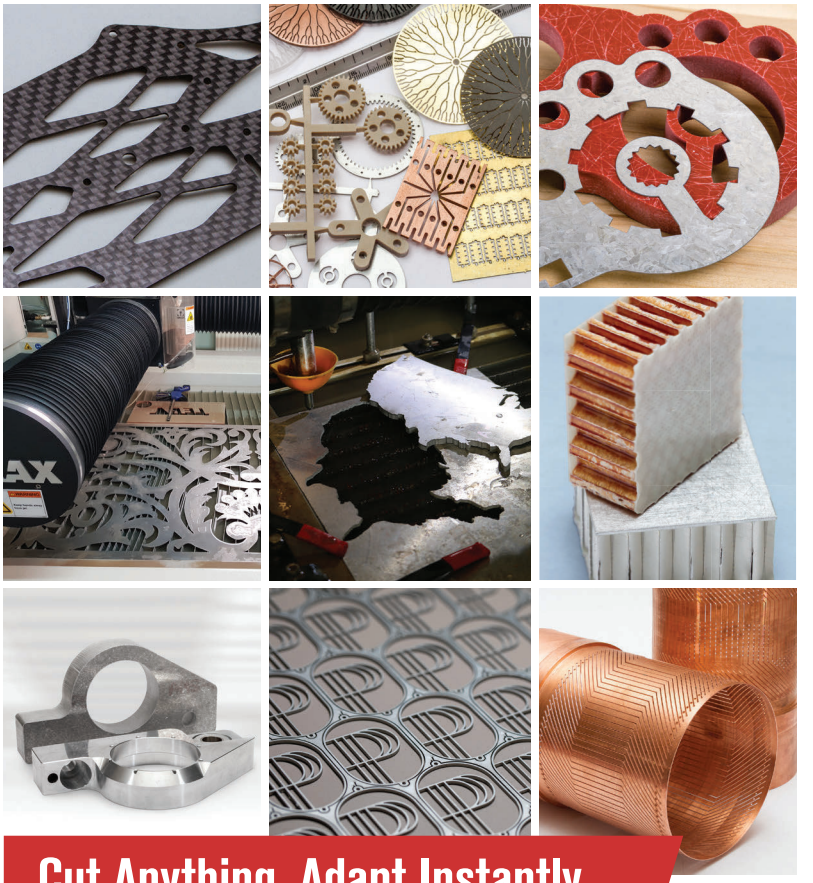
The default only works if the program and the machine support it, and that takes the programmer and the operators agreeing on a few things. On the programming side, restart points must exist before anyone can use them. Clear separation between tool paths with a safe start block at the head of each tool. Sequence numbers at the top of each tool path and nowhere else, so a search lands on a restart point rather than a random block. Subprograms where a single tool path needs to be callable on its own. And a purposeful stop that says why it is there.

On the machine side, the goal is to catch the stop early, while the part is still worth saving. Broken tool detection stops the cycle when the tool goes, rather than after it has cut air through a finish pass. Spindle load monitoring catches the overload before the tool breaks or the part moves. Probing after a restart confirms the part is still where the program thinks it is. These are the same options that make a process secure enough to run unattended, and that is not a coincidence. A process that recovers well is one that stopped early enough to have something left to recover.

With those in place, the operator's job before cycle start is short and it should be posted at the control. The tool in the spindle matches the program and its offset is current. The work offset is right. If any of those is unknown, back up to a point where it isn't.

The restart type, the inputs that would change it, and the program and machine features that make it possible are all decisions a shop can make once. After that, an unexpected stop is a procedure the operator runs, not a judgment call they make alone at the machine.

AUTHOR | John Miller
Owner, Way of the Mill LLC



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Milling Chatter Explained: The Physics Behind Tool Vibration

Wavy surfaces, variable chip thickness and feedback loops all contribute to milling instability. Here's a step-by-step breakdown of the mechanics and math behind chatter and how to predict it.

TONY SCHMITZ | COLUMNIST

In milling, the cutting tool is not rigid, so the cutting force causes tool vibration. When the tool is vibrating as it removes material, these vibrations are imprinted on the workpiece surface as a wavy profile. The wavy surface left behind by tooth 1 is removed by tooth 2 and so on. This provides a feedback mechanism because the instantaneous chip thickness depends on both the current vibration and the surface left by the previous tooth (created one tooth period, or time from one tooth to the next, earlier). The variable chip thickness causes a variable cutting force which, in turn, affects subsequent tool vibrations. The result is the possibility for instability, or chatter. We consider vibrations normal to the cut surface to determine the chip thickness. This normal direction (through the cutting edge toward the tool center) constantly varies as the tool rotates.

The relative phasing between the surface waviness from one tooth to the next determines the level of force variation and, together with the axial depth of cut, whether the operation is stable or unstable (chatter). »

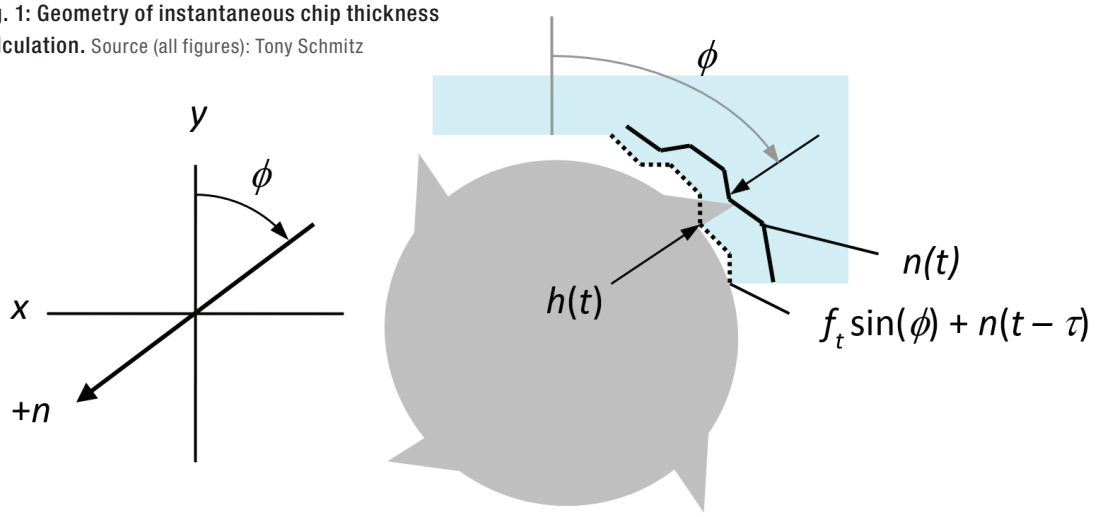
Equation 1.

$$h(t) = f_t \sin(\phi) + n(t-\tau) - n(t)$$

Equation 2.

$$n = x \sin(\phi) - y \cos(\phi)$$

Fig. 1: Geometry of instantaneous chip thickness calculation. Source (all figures): Tony Schmitz



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The phasing between one tooth and the next can be in phase or out of phase. An out-of-phase relationship can cause significant variation in the chip thickness. This can lead to chatter, depending on the axial depth, due to the force variations and subsequent tool deflections.

As noted, the chip thickness is measured along the surface normal, which depends on the tool angle, Φ. If the tool experiences vibrations in the *x* and *y* directions, the chip thickness is affected. The instantaneous chip thickness is described by Equation 1, where f_t is the feed per tooth, $f_t \sin(\Phi)$ is the chip thickness variation without vibration, $n(t)$ is the current vibration along the surface normal direction, $n(t\text{-}\tau)$ term is the vibration along the surface normal left by the previous tooth, and τ is the tooth period in seconds. Also, $\tau = 60/\Omega N_t$, where Ω is the spindle speed (rpm) and N_t is the number of teeth.

The projection of the *x* and *y* tool vibrations along the surface normal is performed using Equation 2.

The geometry of Equation 1 is shown in Figure 1. Larger (more positive) vibrations by the previous tooth increase the chip thickness because less material is removed than commanded. Larger vibrations by the current tooth decrease the chip thickness by the same logic.

To model milling stability, we can assume an average angle of the tooth in the cut and, therefore, an average force direction. We can then derive directional orientation factors to first project this force into the *x* and *y* vibration mode directions and, second, project these results onto the surface normal. Depending on the feedback system gain, represented by the axial depth, *b*, and the spindle speed, Ω, the milling operation is either stable or it exhibits chatter. To calculate a stability map that separates combinations of spindle speed and axial depth that produce chatter from those that do not, use Equations 3-5.

Equations 3-5.

$$b_{\lim} = \frac{-1}{2K_s \,\mathrm{Re}[FRF_{orient}]N_t{}^*} \quad (3)$$

$$\frac{f_c}{\Omega N_t} = N + \frac{\varepsilon}{2\pi} \quad (4)$$

$$\varepsilon = 2\pi - 2\,tan^{-1}\left(\frac{\mathrm{Re}[FRF_{orient}]}{\mathrm{Im}[FRF_{orient}]}\right) \quad (5)$$

In Equation 3, $b_{\lim}$ is the limiting axial depth to avoid chatter, K_s is the specific force that relates the cutting force to the chip area, FRF_{orient} is the oriented tool tip frequency response function that includes the directional orientation factors, Re indicates the real part of the oriented FRF, and $N_t{}^*$ is the average number of teeth in the cut. This average value is calculated by dividing the difference between the exit and starting angles by the angular tooth spacing. In Equation 4, f_c is the chatter frequency (should it occur).

The milling stability map is generated by:

- determining the oriented FRF and identifying the valid chatter frequency range(s) (that is, where the real part is negative)
- solving for ε, the phase between the current and previous tooth vibrations, over the valid frequency range(s)
- finding the average number of teeth in the cut for the selected radial immersion
- calculating $b_{\lim}$ over the valid frequency range(s)
- selecting an *N* value (integer number of waves between teeth) and calculating the associated spindle speeds over the valid frequency range(s)
- plotting Ω vs. $b_{\lim}$ (both are a function of the same frequency vector, so the first spindle speed value corresponds to the first limiting chip width and so on) for each *N* value ($N = 0, 1, 2, \ldots$).

This sequence of steps represents a mapping of the real part of the oriented FRF onto the (Ω, $b_{\lim}$) domain. Any (Ω, $b_{\lim}$) pair that appears above the collective boundary indicates unstable behavior (chatter), while any pair below the boundary indicates stable cutting. In the following slotting example, we'll demonstrate calculation of the stability map.

For this example, the *x* and *y* direction dynamics are described by a natural frequency of 500 Hz, a stiffness of 8×10^6 N/m, and a damping ratio of 0.02. We'll assume

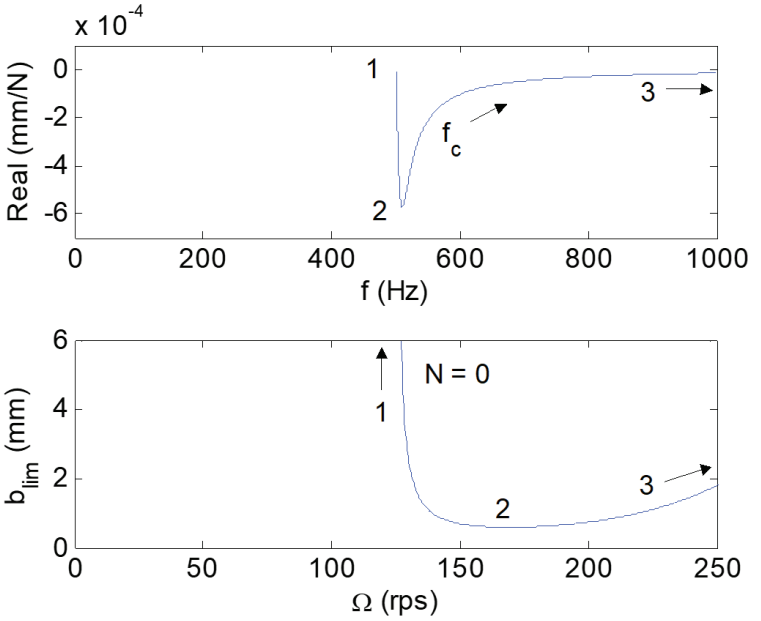
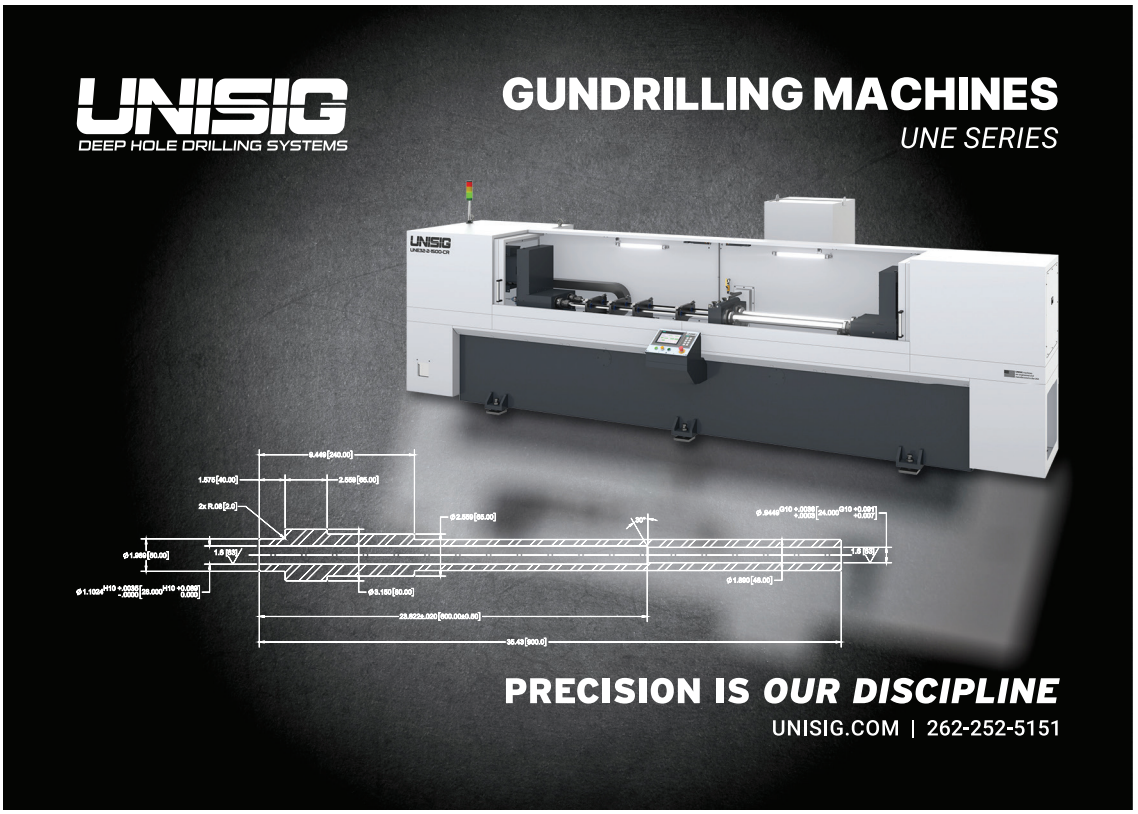


Fig. 2: Mapping of the oriented FRF (top) onto the (W, blim) domain (bottom).

an aluminum alloy machined with a four-tooth, 19-mm diameter square end mill that together exhibit a specific force of 750 N/mm^2 and a force angle of 68 degrees. The average number of teeth in the cut is $N_t^*=2$ for this slotting example.

The mapping is demonstrated by Figure 2. The top panel displays the negative portion of the real part of the oriented FRF. The bottom panel shows the corresponding stability boundary. We see that the minimum value of the real part of the oriented FRF defines the minimum value of the stability boundary. These are identified as point 2 in each case.

AUTHOR | Tony Schmitz
Distinguished Technical Fellow, MSC Industrial Supply Co.



Is Just-in-Time Dead? Rethinking Manufacturing Inventory

Supply chain instability has forced manufacturers to rethink lean inventory — but the answer isn't stockpiling everything. Here's how to find the right balance for your business.

MIKE SIBLEY | COLUMNIST

For years, manufacturers have worked toward keeping inventory as lean as possible. The idea behind just-in-time is pretty simple: Get what you need when you need it, and don't tie up a bunch of cash sitting on a shelf. That still makes sense.

But the last few years have made manufacturers take another look at how much inventory they really need. We've had COVID, supply chain disruptions, geopolitical issues, wars, tariffs and changing lead times. Things that used to feel pretty predictable aren't always predictable anymore. So is just-in-time dead? I don't think so. But I do think manufacturers need to look at it differently.

There are manufacturers that have very sophisticated just-in-time systems. Their suppliers have visibility into their forecasts, they understand lead times, and they've built systems around keeping inventory levels lean. Then there are a lot of manufacturers that never really had that kind of system. We're still seeing companies that have too much inventory. They may be carrying months of material because they don't want to run out, but they haven't really stopped to figure out how much they actually need. So the question isn't just "How little inventory can we carry?" It's "What's the right amount of inventory for our business?

I think the first thing you have to do is understand the risk. Who are your key suppliers? Do you have one supplier or several? What's the lead time? Is the material coming from overseas or is it domestic? How reliable is the supplier?

Your supplier's risks become your risks. That's why I think manufacturers need to look at inventory by risk instead of just looking at one overall inventory number. Some inventory may be easy to replace, while other inventory may shut down the plant if you don't have it.

As you navigate these decisions, this is key: Don't react to every headline. This is where planning becomes important. One week we're worried about tariffs. Then there's a change. Then there's a shipping issue somewhere in the world. Then that changes. You can spend all your time reacting to what's happening that week. I don't think that's a good way to run a business. I like starting with a baseline of what is normally needed. Then look at the risks around that baseline. Which suppliers are higher risk? Which materials have longer lead times? Where do we need some additional inventory to protect ourselves? That gives you a plan without having to completely change your strategy every time something happens.

And then you have to connect that back to the financials. What does that mean for working capital? What does it cost us to carry that inventory?

There's nothing wrong with carrying some safety stock. In some cases, it's absolutely the right thing to do. But you can go too far. If you're carrying an extra million dollars of inventory, that's a million dollars of working capital that's tied up. And there's more than just the cost of the inventory. You've got warehouse space. You've got people moving it. You've got handling costs. And you've got the risk that some of it eventually becomes obsolete.

I also think we're seeing manufacturers look at suppliers differently. Price is important, but it's not the only thing. What's the quality like? What's the lead time? How reliable are they? What happens if they have a problem? Do we have another supplier we could go to? Maybe you don't move all of your business to a second supplier. Maybe you split it 75/25 or 50/50. You're paying for some diversification, but you're also keeping another option available if something goes wrong.

One of the questions I like to ask is how do you »

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know whether your inventory strategy is actually working? Start with the balance sheet. Look at your cash conversion cycle.

How many days of inventory are you carrying? How many days of accounts receivable? How many days of accounts payable? Look at working capital.

Then go to the income statement. What's happening to gross margin? What's happening to contribution margin? What are material costs doing as a percentage of sales?

And I like getting down to the product level. What are the margins by product? Where are material costs changing?

Then go back to the inventory. How much old inventory do you have? How much is becoming obsolete? Are you constantly writing inventory down or throwing material away? If that's happening, there's probably something wrong somewhere. Maybe it's forecasting. Maybe it's purchasing. Maybe it's the product mix. But the numbers are telling you there's a problem.

Purchase price variance is another aspect to consider. What did we think the material was going to cost, and what are we paying? There's a lot of information there if you take the time to look at it.

As we look ahead, I think this is where manufacturers need to spend some time now. Start with what you know. Are the industries your customers serve growing? Are they slowing down? Build the baseline, then ask what the risks and opportunities are. What's our downside? How do we mitigate it? What's our upside? What do we need to do to go after it?

Then bring the supply chain into that conversation. Can we negotiate better supplier pricing? What are tariffs going to do to our costs? What are our inventory requirements going to look like? How does that affect pricing? How does it affect margins? All of those things are connected.

So no, I don't think just-in-time is dead. The right answer to all these questions depends on your suppliers, customers, lead times, risks and financial position. So I think the better question is: *What inventory do we need to run the business, protect ourselves from reasonable risks and still manage our working capital?*

That's the question I'd start with.

AUTHOR | Mike Sibley
Partner, James Moore Manufacturing Services

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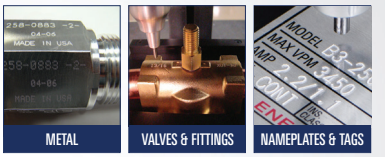
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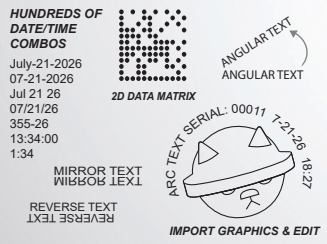
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Metalworking Index Holds Steady in September

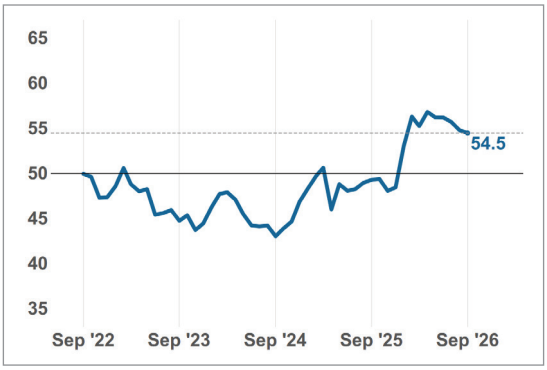
The reading barely moved at 54.5, with new orders, employment and backlog all nudging higher as production lost ground.



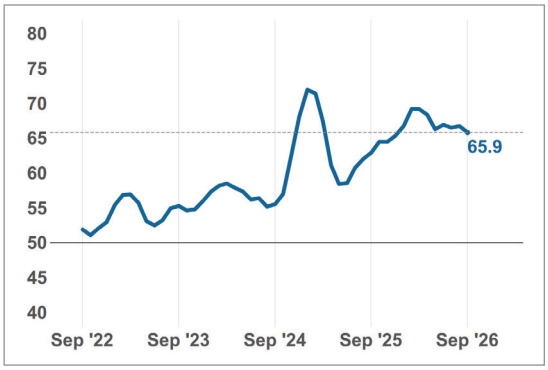
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Mike Shirk
SENIOR MARKET RESEARCH ANALYST

METALWORKING INDEX



FUTURE BUSINESS INDEX



The Gardner Business Index (GBI): Metalworking measures the current state of metalworking and machining activity through survey responses covering new orders, production, backlog, employment, exports and supplier deliveries. A reading above 50 indicates expansion, and a reading below 50 indicates contraction.

The GBI Future Business Index is an indicator of the future state of the metalworking market from industry respondents regarding their opinion of future business conditions for the next 12 months. A reading above 50 indicates expansion, and a reading under 50 indicates contraction.

GBI COMPONENTS SCORECARD

	Change vs Month Ago	Change vs Year Ago
Supplier Deliveries	▲	▲
Production	▼	▲
New Orders	▼	▲
Backlog	▲	▲
Employment	▼	▲
Exports	▼	▲

Source (all figures): Gardner Intelligence

The GBI Components Scorecard reports the monthly change rate of primary metalworking market factors contributing to the overall monthly index reading.

Reading the Scorecard:

- **Color** indicates *where* a component value falls relative to 50 for the current month. Green indicates expansion, and red indicates contraction.
- **Shade** indicates a value's distance from 50. The darker the shade, the further from 50.
- **Direction** indicates a value's change versus the previous period. Pointing up is always better.

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Automating Your Workholding: Readiness, ROI, & Real-World Results

Manufacturers everywhere are feeling the same squeeze: a shrinking skilled talent pool, customers demanding higher quality and faster deliveries, and competitors leveraging automation to cut costs and lead times. The instinct is often to buy another machine, but for most shops, the real bottleneck isn't capacity — it's everything happening around the spindle.

PRESENTER: **Jim McCullough,** Sales Engineer, All World Machinery Supply

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The Real Measure of IMTS: Bringing Discovery Home

Michelle Edmonson, CEM
VICE PRESIDENT, EXHIBITIONS

AMT – The Association For Manufacturing Technology, which owns and operates IMTS – The International Manufacturing Technology Show

Two months after IMTS 2026, I've had time to reflect on those six days at the largest manufacturing show in the Western Hemisphere.

IMTS – The International Manufacturing Technology Show brings the manufacturing community together in Chicago every two years to explore new technologies, solve production challenges and build relationships across the industry. This September, manufacturers filled McCormick Place to see technology in action, talk directly with experts and consider what could make a difference in their own operations.

But the real measure of IMTS isn't what happens during those six days. It's what happens next — when manufacturers bring those discoveries home and put them to work.

Across IMTS 2026, manufacturers of every size, from job shops to large OEMs, came with real production goals: increase capacity, make difficult parts more efficiently, automate processes, improve inspection and prepare for new business.



Austin Davis of RoboJob USA, Tavis Vaughn of CNC Machine Products and Mark Taylor of Concept Machinery at IMTS 2026.

Tavis Vaughn, vice president of engineering at CNC Machine Products, is a great example.

Tavis came to IMTS seeking a better way to produce a thin-walled bearing race for an aerospace customer. His search led him across several technology sectors. He evaluated the Mazak Integrex J-300 for milling, turning and drilling; explored automated loading from RoboJob and workholding from Schunk; and compared inspection technologies from Renishaw and Hexagon.

One part brought together machining, automation, workholding and quality — and gave him the opportunity to talk directly with the people behind each technology.

In another example, Tom Bassett, owner of the precision job shop ProCam Services, demonstrated what can happen when those discoveries become investments.

"We bought our first DVF 5000 last show," Bassett says. "It created a backlog because we have so much work that needs five-axis capabilities, so we purchased two more [from DN Solutions] this year."

That is an exciting cycle to see: a shop adds capability, wins work that benefits from that capability, and returns to IMTS ready to expand again.

No matter what you make or what role you play in manufacturing, you can find people who share your interests, challenges and priorities. That's why IMTS always feels like home. We heard story after story of connections made here that will lead to new ideas, solutions and opportunities long after the show ends.

Those stories are the real measure of IMTS – what manufacturers discover, who they meet and what they bring home to put to work.

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What IMTS 2026 Said About the Future of Manufacturing

Bonnie Gurney
VICE PRESIDENT, STRATEGIC PARTNERSHIPS AND INDUSTRY RELATIONS

AMT – The Association For Manufacturing Technology, which owns and operates IMTS – The International Manufacturing Technology Show

At IMTS 2026, the biggest conversations focused on what manufacturers will be asked to make next — and the technologies that will help them make more of it.

Across the IMTS+ Main Stage and conference programming, speakers from defense, aerospace, technology, machine builders and manufacturing organizations echoed several themes: increasing production, strengthening the industrial base, adopting automation and AI, and giving manufacturers tools to get more from their people and equipment.

Vice Admiral Robert Gaucher, director of submarine programs, brought the need to increase production capacity into sharp focus.

"As we build the future submarine fleet, we must take advantage of technology and advanced manufacturing from the start," Gaucher says. "IMTS 2026 shows our industry partners are ready to meet this challenge. Robotic assembly, automated tools and additive manufacturing are exactly what we need to generate immediate output to support our warfighters at scale."



Vice Admiral Robert Gaucher, director of submarine programs, delivers his address, "Steel to Sea: Scaling Undersea Superiority with Manufacturing and Technology" on the IMTS+ Main Stage at IMTS 2026.

Gaucher was joined at IMTS by other Navy leaders, including Capt. Jason Deichler and Capt. Kevin Moller, as defense manufacturing took a prominent role in conversations about expanding U.S. production capacity.

Industrial AI was another recurring theme. Speakers and participants from AWS, Google Cloud, Microsoft, Siemens, Intrinsic Innovation and others discussed how AI is moving from possibility to practical manufacturing applications.

Steve Blackwell, leader of AWS Product Engineering & Services Center of Excellence, said leading manufacturers are already deploying AI and realizing gains in efficiency, quality and agility.

Speakers from Lockheed Martin, EOS, NASA, Oak Ridge National Laboratory, Sandia National Laboratories, Red Bull Racing, Rivian, SME, Manufacturing USA and other organizations built awareness and understanding of AI, automation, software and advanced manufacturing technologies, encouraging manufacturers to accelerate adoption to solve complex problems, optimize operations and increase productivity.

The conversations and discoveries from IMTS 2026 continue at IMTS.com, where you can watch IMTS+ Main Stage sessions, revisit exhibitors and technologies, and connect with the people and companies moving manufacturing forward.



My AMT Leadership Forum group offers so much collaboration. Members are from machine tools, accessories, and other industries, and their experience levels are likewise diverse. So, when we discuss business issues, you get so many different opinions and perspectives that you learn new solutions and ways to approach situations that you may not have encountered before.

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Technology to Keep Production Moving

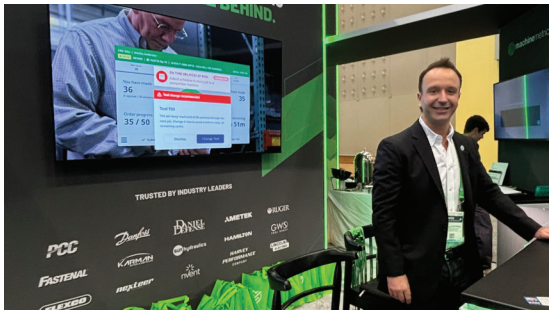
Kathy Keyes
MANAGING EDITOR

AMT – The Association For Manufacturing Technology, which owns and operates IMTS – The International Manufacturing Technology Show

Six days at IMTS – The International Manufacturing Technology Show were enough to fill my notebook, but not nearly enough to tell every story. Throughout the coming year, I'll continue reporting on the technologies, applications and people I encountered at the show. For now, these examples share a common theme for manufacturers: fewer production bottlenecks and more time spent making parts.

MachineMetrics introduced Max AI, the intelligence layer within its new MaximaOS manufacturing operating system. Max AI combines live machine data, ERP context and a manufacturer's documented knowledge, enabling teams to ask questions, investigate issues and receive guidance during production. The value of moving from retrospective reporting to real-time action is already evident at Max Aerostructures. The aerospace supplier used MachineMetrics to turn lagging KPIs into lead measures, giving managers and operators timely alerts and a clearer view of equipment utilization.

Royal Products demonstrated how workholding can unlock the capacity of a five-axis machine. In one customer application, eight pallets were each equipped with a Royal SLV Multi-Vise Pyramid holding three vises, creating 24 staged workholding stations. The compact arrangement improved tool access and enabled five-sided machining with shorter, more rigid tooling. According to Royal, the vises' boxway construction and elevated drive spindle provided sufficient holding force to eliminate the need for a separate dovetail preparation operation. The customer now produces more than 400 stainless steel parts per shift and runs unattended after hours.



Graham Immerman, chief revenue officer at Machine Metrics, introduces Max AI at IMTS 2026.

For much larger parts, SW North America unveiled the BA Space5-12H, a five-axis machining center that offers a 4,800-by-1,800-by-875-mm work area, an architecture designed for automation and digital twin capabilities. Initial aerospace applications include structural frames, titanium window frames and seat structures. SW estimates that the platform can deliver up to 30% greater productivity in targeted applications.

3DChimera demonstrated that 3D printed production tooling can be stronger and more practical than it looks. Its soft jaws, made from glass-fiber-reinforced nylon filament, provide stiffness and strength approaching those of 3000 series aluminum while creating a nonmarring surface. An outsourced aluminum jaw may take five to 15 days, while 3DChimera can produce a printed version in two to three days. A shop with a suitable printer can make one from a supplied file the same day. The expertise lies in matching design, material, equipment and print parameters to the application.

From AI-guided decisions to 3D printed tooling, high-density workholding and large aerospace machines, these technologies show how many different paths can lead to better production. This is only the beginning of my IMTS 2026 coverage. I'll share more discoveries throughout the year. In the meantime, visit **IMTS.com** to explore exhibitors and connect with technology suppliers.


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The Bechtel Innovation Design Center is a makerspace on Purdue University's campus that gives students access to material, equipment and peer mentors to make parts for various projects and activities. Members of the Purdue Space Program and automotive teams are the primary users of the center's CNC lab, which has four milling machines and two lathes. Source (all images): Purdue University

Heat-Shrink Toolholders Help University CNC Lab Reach Full Potential

A heat-shrink toolholding system donated by Haimer is helping students make parts for aerospace and automotive competitions at Purdue University's Bechtel Innovation Design Center.

CARY LEIMER, LIAM MROCZEK AND ATULRAM VUCHA |
METAL SHOP SUPERVISORS AT BECHTEL INNOVATION DESIGN CENTER

The Bechtel Innovation Design Center is a 32,000-square-foot makerspace on Purdue University's campus that gives free access to material and machine time so students can turn ideas into real parts. The center includes eight labs for woodworking, composites, 3D printing, welding and jewelry fabrication, blacksmithing, electronics, fabrics and CNC machining.

Students bring their ideas to one of more than 150 peer mentors who start the production process by evaluating the student's designs. After approval, the student works with another peer mentor on the shop floor. "The peer mentor is teaching them how to run the machines so that the student wanting the project done becomes the maker," explains Paul McPherson, associate professor of practice and director of the Bechtel Innovation Design Center at Purdue University.

The CNC lab is equipped with a UMC-500 five-axis machine; VF-3 three-axis machine; two VF-4s, one of which has a fourth axis add-on; and an ST20 and ST20Y lathe, all from Haas. According to McPherson, the CNC lab's primary users are members of Purdue Space Program, an interdisciplinary student-run rocketry and space exploration group, and automotive teams such as Baja and Formula SAE.

The center's role as an R&D and training lab means it faces some specific challenges. "We are working with students from the whole spectrum of experiences, from never having done a CAD design to 'I'm making an injector for a rocket part,'" McPherson notes. Students with less experience may not have grasped how to design for manufacturability. Students' project timelines also often don't allow for multiple iterations of a part. "It's hard for [students] to keep redesigning and running numbers on new geometries," explains Anirudh Pal, metal shop manager at the Bechtel Innovation Design Center. On top of that, the CNC lab is very busy. McPherson says the lab completed 4,100 projects in the spring 2026 semester alone and estimates it takes on between 6,000 and 7,000 projects during the course of the academic year. This means maximizing spindle uptime is essential.

Deep Problems

One of the CNC lab's major bottlenecks was its toolholders. The lab was using hydraulic milling chucks as its standard toolholders, which provided rigidity, low runout, good balance and general versatility. However, their large profiles created issues with clearance on the types of deep-reach parts aerospace and automotive teams often need to machine.

"Some of the parts that they're making are something like an upright. So, when they are manufacturing the upright, there might be regions that are a little hard to reach with standard tooling," Pal explains. "When it comes to the aerospace teams, they're working on pretty deep cylindrical work, and they're also using it for deep reach and surfacing inside of cylinders." Take a rocket chamber, he continues. It has a narrow throat, making it difficult for bulky toolholders to reach the bottom of the part.



The lab's hydraulic milling chucks provided general versatility, but were not suited to parts with deep features, such as this tower. Even its long-reach ER holders had a wide profile that restricted the design of these parts, which are common among the parts the aerospace and automotive teams need to make.



Haimer donated enough shrink-fit toolholders for all four of the center's milling machines, along with a Power Clamp Comfort i4.0 shrink-fit machine. Students can scan a Data-Matrix code on the toolholder to see shrinking parameters. Combined with the NG coil, these help ensure consistent and reliable tool setups, even with beginner machinists.

"The ER holders have a pretty wide side profile, even the long-reach ones," he says. "And that really restricts the geometry of nozzles you can make." Additionally, the ER holders were less rigid and needed to be assembled and disassembled, eating into the limited time the students have reserved to complete their projects. But an encounter with Haimer resulted in a more efficient toolholding system for the lab.

Heating Up Productivity

At IMTS 2024, representatives from the Bechtel Innovation Design Center's CNC lab were in the booth of a workholding partner. That booth was located near Haimer's, and the center's then-director connected with representatives from the tooling supplier. Haimer eventually paid a visit to the Bechtel Center and sponsored a new heat shrink tooling system for the center's CNC lab. The donation included standard and Power shrink-fit toolholders along with a Power Clamp Comfort i4.0 machine.

Haimer says its shrink-fit toolholders are balanced to 25,000 rpm, increasing concentricity and reducing runout. It also designed its Cool Jet technology to enhance through-spindle coolant delivery at all speeds, ensuring coolant is delivered at the cutting edge to remove chips from the cutting area without coning out. Its rigidity lowers the risk of pullout, while its slim design allows for better clearance on deep parts.

The Power Clamp Comfort i4.0 shrink-fit machine uses induction technology for consistent heating. The NG coil enables users to automatically configure the coil for the toolholder they're using without needing to manually adjust with stop discs. This ensures the coil heats the toolholders only where needed. Pal says this setup makes the coil easy to use, which is important because many of the center's users have limited machining experience. "We don't want to overburden our students with choosing the right configuration and having severe consequences for choosing the wrong configuration," he says. The lab's shrink-fit unit is equipped with a handheld scanner that reads Data-Matrix codes on the



Haimer also donated a set of Centro coaxial indicators for the lab's lathes. Users can switch from ID to OD with a turn of a dial instead of disassembling, reassembling and recentering the indicator, speeding the process of indicating toolholders.

toolholders and gives shrinking parameters to take the guesswork out of toolholder assembly. "The system allows us to just scan the tool, and it gives you on the screen what the NG coil needs to be, which cooling sleeves you are supposed to use and how long it'll take to heat," Pal says.

The system also includes a contact cooling system with a closed-loop active chiller that speeds cooling, keeps toolholders dry and free of rust, and ensures even cooling to reduce runout. Temperature sensors in cooling jackets give users a visual indicator of whether the holder is safe to touch.

Another Tool in the Toolbelt

The heat-shrink system replaced the hydraulic toolholders as the lab's go-to toolholders for

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The heat-shrink toolholders have reduced setup time and increased spindle uptime, while improving tool life, bettering part quality and increasing the range of geometries students can produce. Additionally, they give students exposure to more types of toolholder options, and they can take that experience with them into the industry.

standard and long-reach applications, while the hydraulic models are now used for specialty tools. Since implementing the system, the lab has seen a range of benefits, including:

- **REDUCED SETUP TIMES.** The lab reports that the shrink-fit system has slashed tool setup time by 15%. "In about four or five minutes, you are ready to go. You're fully assembled for a given tool," Pal says. "In a prototyping shop, which is changing tools often, it's quite useful."
- **INCREASED SPINDLE UPTIME.** Reduced tool setup time has enabled users to increase spindle time by 30% in a given reservation window.
- **IMPROVED PART QUALITY.** The lab reports better part quality thanks to through-tool coolant and increased clearance from narrower toolholder profiles.
- **WIDER RANGE OF PART GEOMETRIES.** The improved clearance also enables users to produce a wider range of part geometries. "It is advantageous for our lab to be able to do more geometries because that makes it easier on the student side," Pal notes.
- **MORE CONSISTENT AND RELIABLE SETUPS.** The system's ease of use means students of different skill sets can successfully set up their tooling.
- **IMPROVED TOOL LIFE.** Pal says this is particularly true in applications with small tools running in harder materials, thanks to the system's reduced runout. "Below three-eighths is where you start to see a difference," he notes. "And when you go to even smaller, it is much more significant."

Haimer donated enough toolholders for all four of the lab's milling machines. "Previously, we had enough holders to have two or three machines running and there were a lot of back-and-forth setup changes," McPherson says.

Haimer also didn't forget the lab's lathes: The donation included a set of Centro coaxial indicators, which Pal says are sturdier than other coaxial indicators he's used. "The stylus attachment is a lot more stable. It's actually a screw-on stylus, whereas most coax indicators use just a set screw," he says. Users can also switch from ID to OD by turning a dial, whereas "on a traditional coaxial indicator you would have to completely remove the pin, disassemble it, and change it, which then you have to recenter. So, it ends up taking a lot more time," he explains. "That definitely makes a huge difference on our lathes for indicating in our toolholders."

Not only did the heat-shrink toolholders help improve productivity in the CNC lab but they also give students more experience with different toolholding technology. "Our objective here is to expose engineers to manufacturing and we want them to see manufacturing as it is in industry, not a couple decades behind," McPherson says. "So having ER, hydraulic and heat shrink gives them perspective. They'll go on to industry and make decisions about manufacturing and knowing the more advanced toolholding options does make them choose better options instead of just sticking with the only thing they have ever seen."

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A Five-Axis Machine With The Right Stuff

A new Trimill milling machine with a five-axis head has enabled aerospace and defense shop Votaw Precision Technologies to take work it wouldn't have previously considered.

JULIA HIDER | EXECUTIVE EDITOR



Votaw Precision Technologies specializes in large ring-shaped parts for the aerospace, spaceflight and defense industries. Many of the parts it machines are destined for space via customers such as NASA and Blue Origin. Source (all images, except where noted): *MMS*

"One-hundred-fifty- to 300-inch diameter rings are our main staple," says Art Talavera, VP of operations at Votaw Precision Technologies. For much of the shop's history, it didn't bother quoting smaller parts. Not because it couldn't make them, but because they weren't the most efficient use of the shop's capabilities. However, a new VFC 3021 milling machine with a five-axis head from Trimill cut cycle times enough that smaller, higher-volume parts it previously wouldn't have considered were now profitable, unlocking a new stream of business.

A Stronghold of American Manufacturing

Votaw was founded in 1963 as an independent shop. In 2025, the company was acquired by Cerberus Capital Management, an investment firm. The firm's Supply Chain and Strategic Opportunities platform invests in companies such as Votaw, which do work in areas of national shortage. "They're really not looking to turn the company over," Talavera says. "They're looking to build it and actually have a stronghold in American manufacturing."

The firm was interested in Votaw's capabilities for aerospace, defense and spaceflight applications. Among the parts I saw on a tour of Votaw's two Santa Fe Springs, California, facilities were panels for Blue Origin's New Glenn rocket and Blue Moon lander as well as Starlab, the commercial low-Earth orbit space station that is designed to take the place of the International Space Station (ISS) after its decommissioning. The shop makes parts for EELV Secondary Payload Adapters (ESPAs), which enable orbital launch vehicles to carry secondary payloads, such as satellites, as well as rings for the V-22 Osprey tiltrotor aircraft. In the quality lab, built around a massive gantry CMM, components that enable vehicles to dock to the ISS were being inspected; arms, scanners and trackers

handle Votaw's largest parts as well as in-process inspection and measurement.

Back on the shop floor, operators were in the process of finishing a nozzle for a hypersonic wind tunnel. Machined in 16 pieces, the pieces needed to be blended seamlessly for the wind tunnel to function properly. Each component was attached to the next and the pairing turned together to create a smooth transition. "When we're done, we remove the bottom, lower the top down," add the next part on top and blend those together, Talavera explains. A 460-inch-long mandrel on the shop floor is destined to mold rocket fuel into a starburst shape, providing more efficient burn thrust. Recent work has also included parts for the Orion spacecraft and Space Launch System rocket used in the Artemis II mission.

One thing these parts have in common is that they're large, and large parts require large machines. Votaw's shop floor is filled with massive open vertical turning lathes (VTLs) as large as 300 inches in diameter and portal milling machines. The tour stopped at an enormous pit in the concrete floor ranging to 10 feet deep in places. This pit was the beginning of a foundation for a new horizontal floor mill that will measure 360 inches in X and 158 inches in Y and have a variety of changeable heads including straight spindle, high-speed and rough machining options. It's already booked for "the next year or two after it gets running," Talavera says.

Between the tight schedules on the machine, the amount of work put into each part and long lead times for the forgings (Talavera says the wind tunnel segments have a 36-week lead time), Votaw's biggest challenge is making parts as quickly as possible while keeping scrap as low as possible.



These two pieces of a nozzle for a hypersonic wind tunnel are being turned together to ensure seamless blending. Each of the 16 wind tunnel pieces were blended seamlessly with the next to ensure the wind tunnel works as intended.

One, Two, Tri

Votaw's two Trimill machine tools stand out on a shop floor filled with enormous, open machine tools. The Trimills are large, but they're enclosed.

Talavera first came across the brand while visiting a machine shop to look at a different brand of machine tool. "When I came across it I said, 'Okay, what about this machine here?'" The more he saw and learned about the machine, the more he liked it, but he was hesitant because he had never heard of the brand. Votaw eventually decided to take the leap and purchase a VFC 3021 five-axis vertical milling machine. In the four years since the machine was installed, "It's been a success story," Talavera says. "On day one we were making some good parts."

Talavera was drawn to the machine's accuracy and speed. The VFC 3201 has a maximum spindle speed of 24,000 rpm, exceeding the shop's other milling machines. Fast tool changes (typically five to 12 seconds chip-to-chip) also contribute to reduced cycle times. Combined with the accuracy of the rotating five-axis head, the machine enables Votaw to maximize efficiency. "We were able to run parts much quicker," he says.



At the time of my visit, Votaw was digging a foundation for a new horizontal floor mill that will measure 360 inches in X and 158 inches in Y. Even before installation, the shop has more than a year of work scheduled for this machine.

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Votaw added a VFC 3021 VMC with a five-axis rotary head from Trimill (right) four years ago. The machine's speed, plus its stability and accuracy, have cut cycle times by more than 50% on some parts, leading the company to add a Trimill VU 4525 (left). Source: Votaw

In addition to speed, Trimill machines are designed for rigidity. The VFC 3021 has a single-piece U-shaped base that encompasses the side walls and clamping table. The base and columns are made of ultra-high-performance concrete to damp vibration and increase thermal stability. The machine also uses a "box-in-a-box" design where the crossbeam and cross-slide are enclosed, along with an internally positioned and guided ram unit, which includes the Y- and Z-axes. "The head's got guiderails all the way around on four sides," Talavera adds. "Some machines you'll see are only supported in the front, where they go up and down."

One of the machine's early jobs was running components for the AN/TPS-80 Ground/Air Task Oriented Radar (G/ATOR), an air surveillance/defense and air traffic control radar for the Marines Corps. Votaw is making and assembling the lower portion of the system, which acts as a trailer, for Saab and Northrop Grumman. It's made from aluminum, and all components are riveted together instead of welded. "It's been so successful that the government now is allowing them to sell it to our allies too. So, there's more



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The Trimill's ability to drastically reduce cycle times has enabled Votaw to take on work that's outside its niche of large ring-shaped parts. This is one of 132 rails for Blue Origin, an example of a job that is now viable for Votaw thanks to the Trimill.

orders," Talavera says. "We did about 30 so far, and there's another 70."

The shop conducted time studies to see how the new machine's performance compared to the previous machine used for these parts, which showed that the Trimill cut machining time by more than half. "Originally, we had slated 1,600 hours for a particular run of the parts, and we got them done here in about 700 hours," Talavera says. "So, it knocked off almost 900 hours."

In addition to the machine's performance, Talavera says he appreciates its compactness. Votaw handles so many large parts that the more machines it can fit on its shop floor, the better. It's also small enough that it did not require a dedicated foundation, like the one I saw in progress elsewhere on the shop floor. He adds that the enclosed machines help keep the area cleaner and quieter. But one of the biggest benefits is the service. "Even though this machine is from the Czech Republic, there's quick access to service," Talavera notes. "That's always a big plus," particularly when the machines have two years of work scheduled as soon as they're up and running. Service is strengthened by the location of the offices of the brand's local distributor, YCM Alliance, which are just a few buildings away from Votaw.

The Trimill proved so successful that Votaw was in the process of installing a second Trimill at the time of my visit. This one, a VU 4525, has a working envelope of 177.16 by 98.42 by 59.05 inches and a maximum part weight of 1,433 pounds per square foot or 15,400 pounds across the table surface. It's slightly larger than the VFC 3021, which has a working envelope of 118.11 by 82.68 by 47.24 inches and has the same weight restrictions. "It's the same story," Talavera jokes. "We buy a machine and we get a job which is a little bit bigger and longer." Beyond the larger footprint, this machine has a rotary table in addition to the five-axis head.

A Foundation For Future Work

As the new machine is being installed, the operators who run the first Trimill are training the operators who will run the new Trimill. This is

> **“It’s been so successful that the government now is allowing them to sell it to our allies too.”**
>
> —ART TALAVERA, *VP of operations at Votaw Precision Technologies*

common at Votaw. Given its niche specialty and the difficulty of hiring experienced machinists, the company has developed a system for training in-house. “We have a lot of folks here that have been here 20 years, and we’re piggybacking off their knowledge when training some of the younger folks.” Having employees ready to run the new machine will be crucial, Talavera says, given the machine’s years-long bookings even before it’s fully installed.

Some of the work on these machines is noticeably smaller than the traditionally large work Votaw does. That’s because the speed of the Trimills is making batches of smaller parts practical for the shop. Talavera points to a part near the Trimills, a rail for Blue Origin. These are used as specialized ground support equipment and integration fixtures that guide, hold, align and move large sections of rockets during assembly. “We work on a lot of bigger stuff, but we don’t shy away from small stuff like this,” he says. “There’s 132 of these small components rather than a big aluminum chunk.” Of course, small is a relative term. These parts are still what many would consider to be large, but before the Trimills, these parts were too small to fit into Votaw’s niche. The Trimills have led the shop to realize that “If we get machines like this, we can knock them out quicker than anybody else,” he continues. Particularly “if the volume is correct and there’s a foundation for future work.”

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| YCM Technology USA Inc. | ycmcnc.com





Mach Medical is an orthopedic implant manufacturer that uses advanced manufacturing technology to address some of the challenges of the orthopedic implant industry, including high inventory requirements and slow time to market.

Source (all photos): *MMS*

Software and Standardization Speed Orthopedic Implant Launches

One base CAD model, one standardized shopfloor approach. These ideas enable Mach Medical to get new orthopedic implants to market as much as 87% faster.

JULIA HIDER | EXECUTIVE EDITOR

New generations of orthopedic implants can speed recovery times, last longer and improve patient outcomes. But new implants are often slow to arrive in the operating room.

"If a company's launching a new system, there's quite a bit of engineering work that goes into that," explains Steve Rozow, co-founder and general manager at orthopedic implant manufacturer Mach Medical. The Columbia City, Indiana-based company must break down each required production and validation step into a repeatable process that meets the strict specifications set forth for medical parts. This process takes place not just for every new implant but also for every size and version of that implant, creating a lot of work that the shop must complete before it can bring new implants to the market.

Mach Medical was founded in 2019 to address challenges in the orthopedic implant industry, including high inventory requirements and slow time to market. To do so, it uses advanced manufacturing technology such as parametric design, product lifecycle management (PLM) software and automation.

Process Transfer

According to Dave Anderson, co-founder and business development leader at Mach Medical, the process of launching a new type of orthopedic implant has three stages: design, engineering/manufacturing transfer and manufacturing scale-up. "The part of that that we wanted to tackle was the middle part: the engineering transfer, the manufacturing transfer," he says. "We wanted to shorten that quite a bit." Rozow estimates that new implants take two to three years to come to market, and at least two-thirds of that timeline is dedicated to engineering transfer. "If companies can shorten that manufacturing transfer portion, it can produce humongous benefits," he says.

During engineering and manufacturing transfer, "you're building out an engineering body of work that effectively represents the translation of design specs to executable manufacturing," Rozow explains. This includes tooling design and the resulting casting or forging, workholding, cutting tools, CNC programming, masking, inspection routines and CMM programming. All of these decisions need to be organized into a workflow, and, because medical is a highly regulated industry, "on top of that, you've got to come up with protocols that demonstrate that you've got a validated process in place," he adds. "You've got to capture routers and BOMs and inspection protocols as well."



Orthopedic implants, such as this knee, can come in as many as 100 different sizes and variations (such as left and right). Lead times for new implants, including building out manufacturing processes for all versions of the implant, can stretch to two years.

Implants come in so many different sizes and versions — as many as 100 for some types of implants — and manufacturing transfer needs to happen for each of those variations. Once the first implant is transferred, there's a lot of "rinse and repeat" work to complete the process for the rest of the family. "That takes a lot of time," Rozow points out, "and if there are design changes that crop up in the midst of that, you have to repeat and iterate through again."

Engineering transfer is not only a time-consuming process but also a resource-intensive one. Rozow estimates that for every implant designer, there could be as many as four engineers working on manufacturing transfer.

Threading It Together

A key element in Mach Medical's plan to compress the manufacturing transfer process is its automation via a digital thread that connects all steps of a part production process, from design to manufacturing to quality. "Siemens had a platform that already allowed for a chunk of that effort to be automated," Rozow says. "So, we worked with them to be able to automate the rest of that engineering work." If one of the manufacturer's customers already works within the Siemens ecosystem, designing implants using Siemens NX, that work can transfer directly into Mach Medical's digital thread. But Rozow says that even if a customer is not a Siemens user, the time saved by automating engineering transfer more than makes up for the time spent transferring everything into Siemens.

Mach Medical makes use of NX's ability to produce parametric models, which can be changed via rules such as dimensions or dependencies instead of manual manipulation. This cuts much of the time the manufacturer would spend creating different versions and sizes of a part. Customers start by designing a master model, "And then off of that, we can parametrically drive all the other sizes," Rozow says. Instead of each size and version of an implant being a separate design, thanks to a bit of customization in the software, "we enter in the different size parameters for all of the parts. So, it becomes more of a spreadsheet exercise, and then we're selecting which size we want to be built off of that."

The master model also serves as the foundation to build out the rest of the production process: "Our CNC programs, all of our inspection programs, all of our fixturing and that sort of thing," Rozow says. The Siemens digital thread



ABOVE: Mach Medical's digital thread in the Siemens PLM stretches from CAD with parametric modeling all the way to inspection. The company has established a closed feedback loop that uses inspection data to automatically kick off corrective and preventative action when needed.

BELOW: Mach Medical has also standardized production processes and tooling as much as possible, from castings and forging to workholding and cutting tools, seen here.



can also aid in generating all of the paperwork required for orthopedic implants, including BOMs, routers and inspection protocols.

All of this data is then automatically sent to the systems on the shop floor, including inspection. "We built our entire quality management system in the Siemens PLM, Teamcenter. We worked with them to be able to manage med-device-compliant workflows," Rozow says. "They had the basic structure in the PLM to manage it, but then we did some customization work to manage things like nonconformances and proper flows that would be ISO 13485 and GMP-compliant, along with CAPAs (corrective and preventative action)."

Orthopedic implants need risk files for each family of parts, with information such as inspection frequency and validated/not validated. The digital thread enables Mach Medical to use this data in a closed feedback circuit. "We are starting to loop that information set into the results of the quality inspections that we're getting, so that we can automate it and kick off a CAPA if it's needed," Rozow says.

According to Rozow, manufacturing lead times for new orthopedic implants using standard methods can take between 12 and 24 months. Mach Medical's approach shortens this timeline to three to four months.

Shopfloor Standardization

Moving from the digital to the physical world, Rozow says standardization is key to streamlining the manufacturing transfer process. "We worked hard to standardize a lot of things that happen out on the shop floor," from tooling and workholding to process flow. Not only does this save resources that would have been used to develop separate tooling for different versions of implants but it also helps the shop automate production. "It does introduce a little bit of cost inefficiency up front, but we can go back once the design is settled and companies are more sure of volumes and we can start to customize that process to be more efficient," he adds.

This standardization not only helps speed engineering transfer of implant families but it also enables the shop to achieve automation of lot sizes as small as one part.

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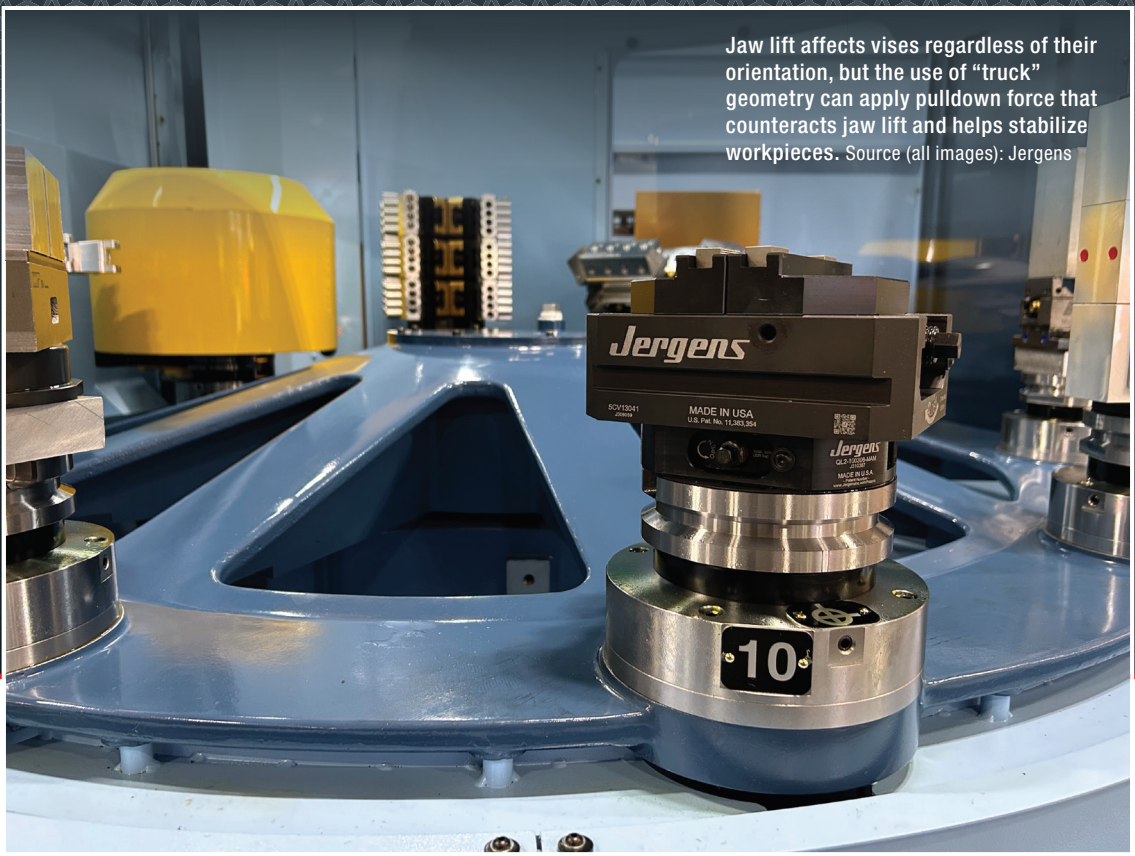
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Jaw lift affects vises regardless of their orientation, but the use of "truck" geometry can apply pulldown force that counteracts jaw lift and helps stabilize workpieces. Source (all images): Jergens

How to Counter Jaw Lift and Wear

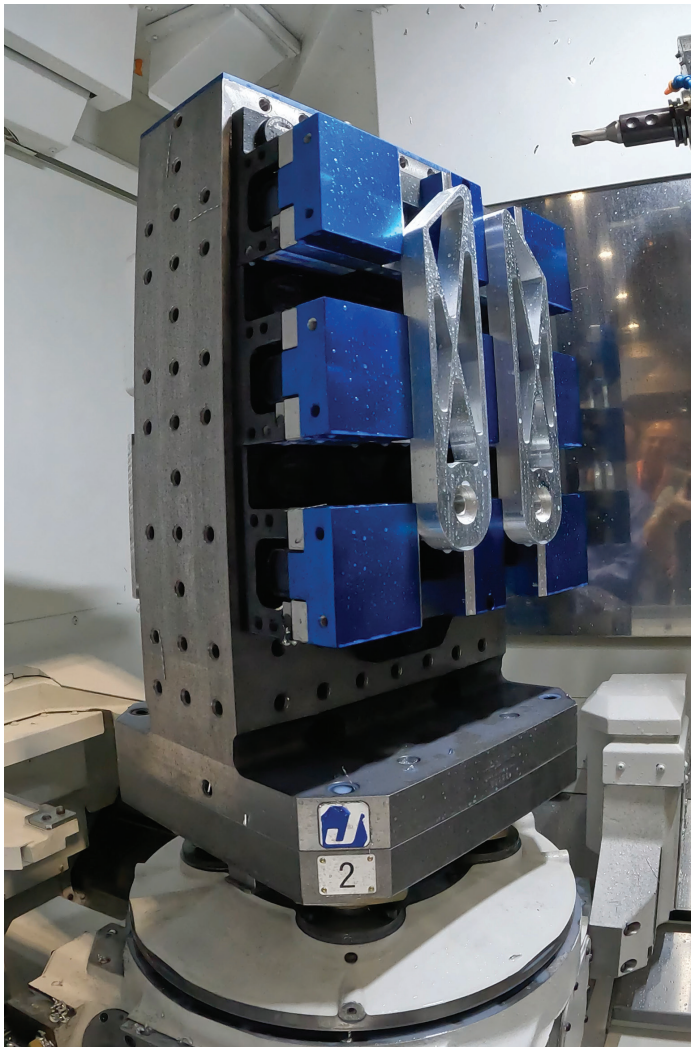
Jaw lift is a natural force that pushes parts ever so slightly out of the vise. Uncontrolled, it can throw ultra-precision parts out of tolerance. Careful planning can counter its worst effects.

EVAN DORAN | SENIOR ASSOCIATE EDITOR

Unchecked, jaw lift can easily add 0.008 to 0.010 inch of runout to a part before you notice it. Even this seemingly small level of error can throw ultra-precise parts out of tolerance and eat up much of the total acceptable runout in others. What's worse, it's impossible to fully get rid of jaw lift — Joe Gorley, Jergens product manager, points out that it is a natural consequence of the physics behind workholding. But, he says, it can be mitigated.

What Is Jaw Lift?

Jaw lift, Gorley says, is a natural torque reaction that pushes a part out when torque is applied to something with moveable parts (such as lead-screws or movable jaws). Whether the orientation



Because jaw lift intensifies every time a jaw is tightened, automated setups that reuse vises are at particular risk of tolerance stack up from jaw lift.

is vertical, horizontal or even inverted, the alignment of the jaws, leadscrew and drive nut will deform the jaw in such a way as to lift the front and change the workpiece position.

If jaw lift begins affecting an operation, it can swiftly lead to accuracy issues. The shifting of the part limits the surface area where the workholding device can apply clamping force, which in turn leads to losses in perpendicularity and parallelism, Z-axis inaccuracies, inconsistency across part runs, and the infiltration of chips between the bottom of the jaw and the bed of the vise. While it can be a surefire way to throw an automated operation off course, it can also lead to errors in complex five-axis work in the span of a single part process.

What Leads to Jaw Lift

While jaw lift is a natural consequence of the physics behind every vise, several factors can exacerbate it. Dried up lubrication on the vise's leadscrew is one of these factors, as are general vise wear and tear and the infiltration of chips (which, as it is also a result of jaw lift, can quickly become a negative feedback loop). Taller parts also shift their center of gravity away from the vise, which can limit gripping efficacy and worsen jaw lift.

Gorley says that while jaw lift does not see direct changes from a shop's machining operations, these operations can affect repeatability and introduce some differences in part position every time you tighten the vise. Relying too much on tightening the leadscrew to compensate for jaw lift and slack also accentuates the wear on it, increasing the odds of the leadscrew breaking. Using a vise for roughing and then switching to finishing (or using a universal vise for high-precision work) also poses risks for the success of the job, as the vise may not have the pressure and force to counter jaw lift.

Mitigating Physics

To counter jaw lift, Gorley recommends addressing the whole sequence of operations, the workpiece and kinds of workholding best suited for each. A basic, utilitarian vise may provide the stability necessary for a simple facing operation, but for high-precision operation, higher-end vises are more likely to resist jaw lift. In particular, Gorley recommends self-centering, low-profile vises with replaceable components.

He also points out the efficacy of "truck" geometries in vise jaws. These create an angle that generates a pulldown motion and downward force. The interplay of forces then becomes a vector question of whether the angle force pushing down (from the truck geometry) is stronger than the angle force pushing up (from natural jaw lift). In a well-designed jaw and operation, the downward force mitigates jaw lift.



One symptom of jaw lift is that chips can fit through the jaws and infiltrate the base due to slack. These chips then cause additional jaw lift and slack in a cycle that quickly compounds. Gorley recommends checking vises regularly for chips and using paintbrushes to remove them.

Other Ways to Leash Runout

Different vises last for different periods of time, and Gorley urges shops to measure the wear their processes place on vises to know whether they will last six months or years. He notes that higher-end vises will be able to take more wear and tear, and often have replaceable parts so shops don't need to dispose of an entire vise over a worn leadscrew or drive nut. He also recommends that shops check on the shape of their vise jaws, as that is where surface-to-surface contact takes place, where even a nick can reduce the gripping force of the jaws and worsen jaw slack or lift.

To prevent these checks from falling through the cracks, he recommends keeping vises in rotation, such that while one vise is in the machine, another is being repaired or rebuilt to be swapped in. As part of this process, he advises using measurements of vise wear to judge when to undertake preventative maintenance and avoid jaw lift issues before they happen. Where possible, he also recommends interchange programs where the vise provider sends new devices on a regular basis. He compares this to changing out your car's tires every so many miles at a known wear rate to avoid potential problems, rather than waiting until your tires look worn.

Ultimately, Gorley advises matching the vise to the operation for the best performance. First, consider the workpiece size and complexity, the required precision, and the clamping force necessary to meet the speeds and feeds. Then think about jaw width and material, the machine table layout, the workpiece material and any special features in the operation (Gorley points out a swivel base for multiaxis work as an example). Whether your goal is to reduce setups, touch points or another factor, achieving this aim will require consideration of the full workholding plan. That way, you can choose the most resilient equipment for your purpose and limit the effects of jaw lift and other causes of runout.

Jergens Inc. | jergensinc.com

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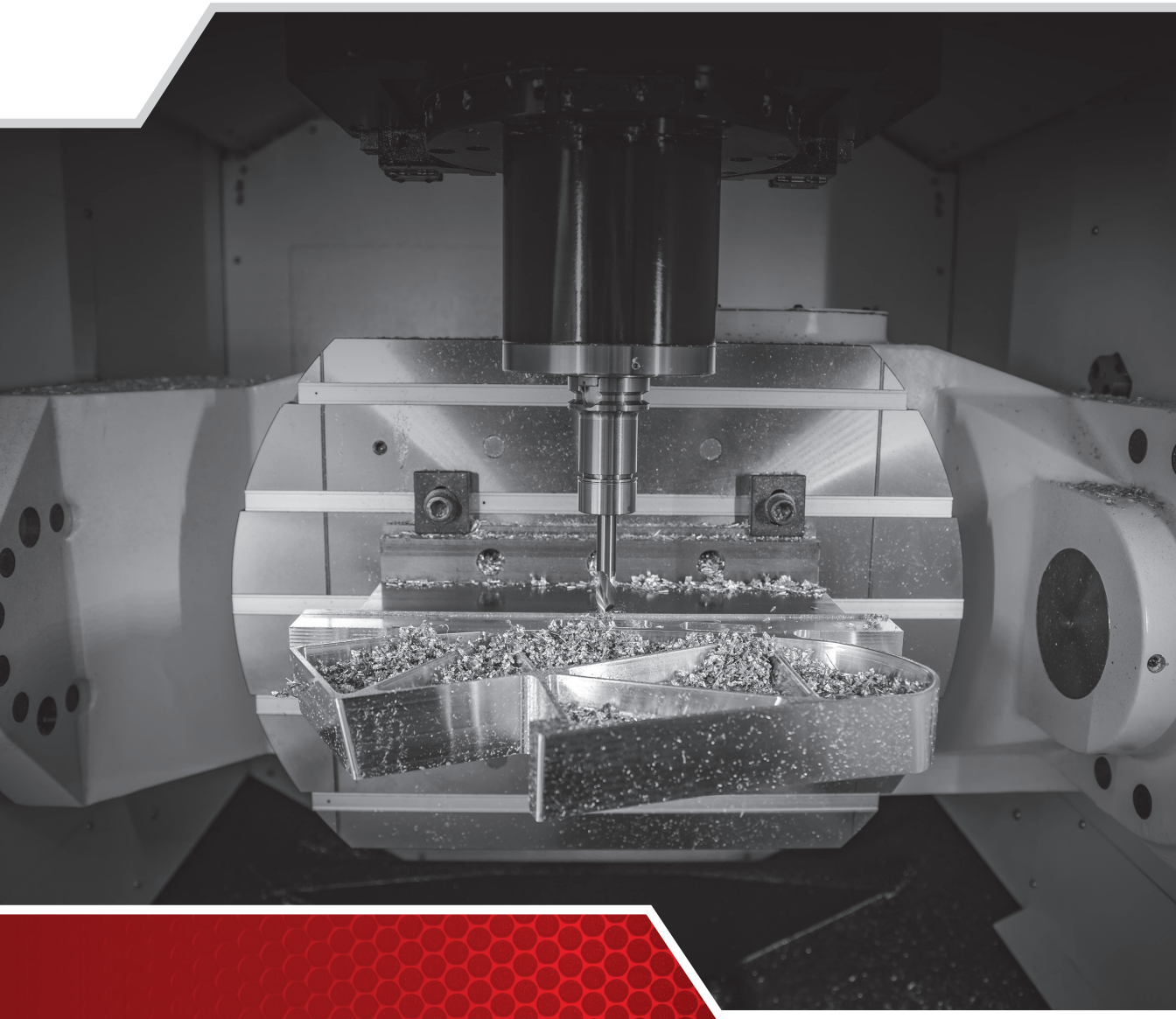
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DN SOLUTIONS



DNX 2100S

Machine Type:	Multi-tasking
Number of Axes:	4+1
Spindle RPM:	12,000



SMX 2600ST:

Machine Type:	Multi-tasking
Number of Axes:	5
Spindle RPM:	12,000 (with 20,000 optional)



DVF 5000 with Multi-level AWC (40 pallet)

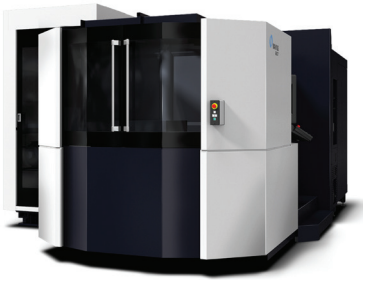
Machine Type:	VMC
Number of Axes:	5
Spindle RPM:	20,000



NHP 5000 with Multi-level DRS (DN Round Storage)

Machine Type:	HMC
Number of Axes:	3
Spindle RPM:	12,000

MAKINO



a630iT

Machine Type:	Horizontal
Number of Axes:	5
Spindle RPM:	10,000 (std.)/8,000 (opt.)/15,000 (opt.)



V300

Machine Type:	Vertical
Number of Axes:	3
Spindle RPM:	20,000



a51nx

Machine Type:	Horizontal
Number of Axes:	4
Spindle RPM:	14,000



EDAF2i Ultra

Machine Type:	CNC Sinker
Number of Axes:	3
Rotation RPM:	300 to 1,000 RPM
XYZ Travel:	13.78" x 9.8" x 9.8"

Star



NXT

Grinder Type:	Tool & Cutter Grinder
Number of Axes:	5
Spindle RPM:	20,000



FLX

Grinder Type:	Tool & Cutter Grinder
Number of Axes:	5
Spindle RPM:	24,000



Tru Tech T93XM

Grinder Type:	Centerless Grinder
Number of Axes:	3
Spindle RPM:	5,000



Tru Tech TT1020M

Grinder Type:	Cylindrical – OD Grinder
Number of Axes:	2
Spindle RPM:	3,000

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Tooling and Workholding

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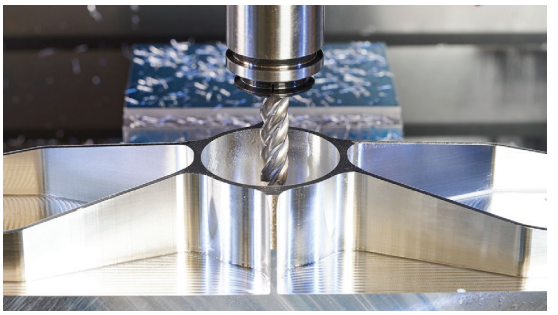
Kyocera SGS End Mill Features Advanced Flute Geometry

Kyocera SGS Precision Tools' S-Carb H5 high-performance five-flute end mill series is engineered for high-production machining of aluminum and other non-ferrous materials. Combining advanced flute geometry, integrated chip breakers, central coolant delivery and Ti-Namite-B coating technology, the S-Carb H5 is designed to provide high material removal rates, optimized surface finishes and reliable performance across a wide range of machining conditions.

The S-Carb H5 supports versatile, high-efficiency milling and finishing applications. Its open-flute geometry is said to promote efficient chip evacuation, while integrated chip breakers shorten chips for improved chip control and increased axial depths of cut. Optimized end geometry improves ramping, stability, chip control and floor finishing, while central coolant delivery further enhances chip evacuation and heat control.

Ti-Namite-B PVD coating technology reduces friction, minimizes built-up edge and extends tool life in aluminum machining applications. Paired with optimized end geometry, the coating is designed to promote smooth, stable cutting and can help minimize secondary finishing operations. The series comes equipped with chip breakers and is available in metric and imperial sizes with square and corner radius options.

Kyocera SGS Precision Tools | kyocera-sgstool.com



Walter Solid Carbide Milling Cutters Extend Tool Life in Hard Machining

Walter USA's MD480 Advance ball nose end mill, MD780 Advance orbital plunge mill and MD880 Advance circle-segment milling cutter feature the high-performance WB10TS grade, which is formulated for hard machining.

The primary application is machining steels hardened to 48 to 65 HRC (ISO H material group), and the secondary application is milling steel (ISO P material group).



The milling cutters enable high metal removal rates due to specialized geometries for hard machining. The optimized micro-geometry of the cutting edge wears more evenly than other designs, resulting in significantly longer tool life. The WB10TS grade also is said to extend tool life.

The MD480 Advance is for finishing 3D contours with radius copy milling cutters. The tool is available in diameters from 0.4-16 mm, with two and four available cutter teeth. A large selection of neck and shank variants are available.

The MD780 Advance features a plunge milling geometry for fast hole production with orbital plunge milling. The tool is available in diameters from 2.5-16 mm.

The MD880 Advance is designed for fast finishing of 3D contours with circle segment milling cutters, with areas of application including tool and moldmaking and general mechanical engineering. The cutter features a conical geometry and is available in diameters from 6-16 mm, with four and eight teeth.

All three cutters feature a cylindrical shank developed according to the DIN6535 HA standard.

Walter USA LLC | walter-tools.com

Seco Tools Turning Grade Improves Stability in Steel Machining

Seco Tools' TP3502 chemical vapor deposition (CVD)-coated Duratomic turning grade is designed to provide stable and predictable tool life for ISO P steel applications, even in interrupted machining and mixed cutting conditions.

TP3502 is developed for steel machining applications where varying material hardness, complex component geometries and interrupted cuts are common. Positioned as a versatile ISO P grade, it is designed to balance wear resistance and toughness across a broad range of applications.



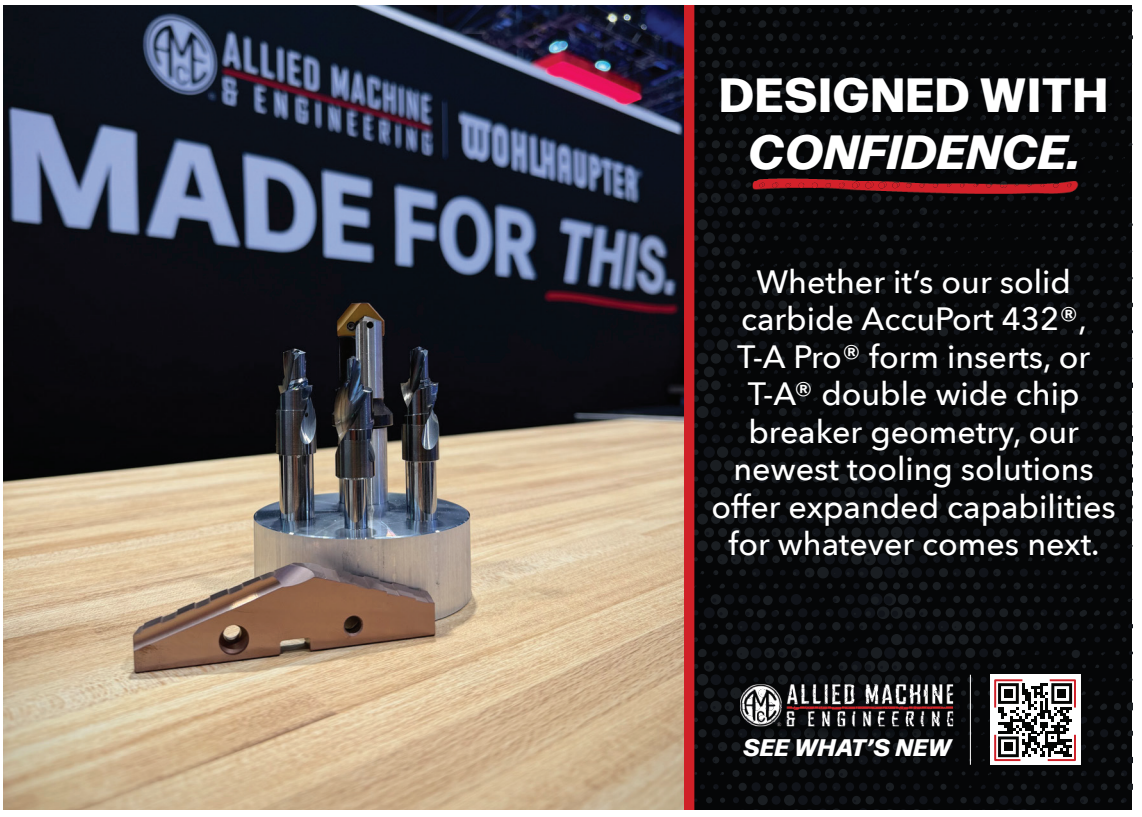
Classified within the ISO P35 range, the TP3502 grade features an updated coating and edge preparation designed to produce a more controlled wear pattern and improved tool life compared with earlier generations. The aim is to enable higher cutting speeds while maintaining process stability and consistent component quality.

TP3502 is a general-purpose grade for steel turning, covering low- and high-alloy steels as well as selected stainless steels, ductile irons and powder-metal components. These applications often involve interruptions and varying cutting conditions, requiring both toughness and reliable performance.

The grade also incorporates features aimed at supporting digitalization and sustainability initiatives. Chrome used-edge detection is intended to help operators make full use of each cutting edge, while a data matrix code enables traceability and digital tracking. TP3502 is produced using recycled powders and is included in a buy-back recycling program, supporting waste reduction and sustainability reporting.

"With TP3502, the focus is on improving process reliability in everyday steel turning," says Mikael Lindholm, global product manager, general ISO turning at Seco. "This stability allows manufacturers to increase cutting data and simplify production planning."

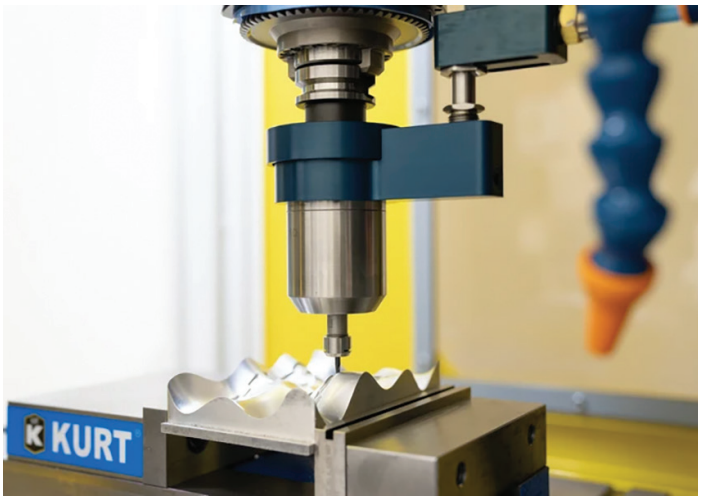
Seco Tools LLC | secotools.com



Air Turbine Tools Drill Tap Series Boosts Production With High-Speed Pneumatic Spindles

Air Turbine Tools' Drill Tap Series of high-speed pneumatic spindles are engineered to help manufacturers increase production, extend tool life and improve surface finish quality on compact drill-tap machining centers. The Drill Tap Series is a quick addition to the magazine of popular machines including Robodrill, Brother, DN Solutions and Haas. With no heat and a governed constant speed up to 90,000 rpm, the Drill Tap Series uses only a dry 90-psi air supply, with no wires, additional drives, converters or lubrication systems required.

The Drill Tap Series is designed to accelerate production in high-speed milling, micro-drilling, engraving, slotting and finishing operations with small tools, where maintaining constant sfm in-cut under load is critical to tool performance and part quality. Consistent high speed under load improves chip formation and reduces cutting forces, which contributes to longer tool life, more predictable tool performance and better dimensional control through long production runs.



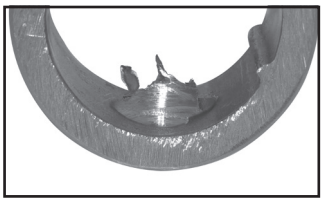
Air Turbine Tools' turbine technology increases cfm air flow volume to respond reactively to cutting load, keeping tool rotation close to rated speeds at 30,000, 40,000, 50,000, 65,000 and 90,000 rpm. These direct drive spindles sustain torque under cutting loads. In addition, these tools operate without vibrating gears, vanes or high-frequency brushes that wear and generate heat in conventional spindle designs.

With only two moving parts and low-friction, air-cooled bearings, Drill Tap Series spindles run with no heat or thermal growth and very low vibration, supporting 2-micron precision and enabling continuous 24/7 operation with no duty cycle and no maintenance requirements.

The Drill Tap Series includes compact single-turbine and powerful double-turbine configurations to match different material and tooling demands. Single-turbine Drill Tap models, such as the 625DT, provide fixed governed speeds from 30,000-65,000 rpm with power ratings up to 0.55 hp (0.41 kW), providing an efficient solution for precision milling, micro-drilling and finishing with small-diameter tools while maintaining surface finish and tight tolerances. For harder materials, larger tools or higher metal removal rates, the double-turbine 625XDT at 0.8 hp and 50,000 rpm provides higher power output, enabling accelerated feed rates and high-speed strategies such as trochoidal milling without sacrificing stability or accuracy.

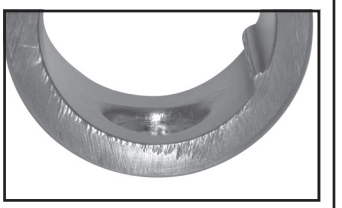
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Kennametal Tooling Portfolio Supports Precision, Productivity Across Range of Applications

Kennametal Inc. announces the availability of several tooling innovations and expanded product offerings designed to help manufacturers improve productivity, reduce costs and machine with greater precision. The tooling products, which span turning, milling, threading and tooling systems, are designed to give manufacturers more opportunities to optimize performance across a wide range of applications. They include:

- **KCP25C:** Seven product lines now feature the KCP25C steel turning grade, providing reliable performance across a broad range of turning applications
- **KCU20B:** A laydown threading grade compatible with most threading systems, offering increased versatility and performance
- **Alumax VM:** Solid end mills engineered for high-speed aluminum machining and demanding aluminum applications
- **KenCut MRAD:** Multi-radius solid end mills designed for five-axis machining and featuring the advanced technology of the KCSM15A grade
- **KOR expansion:** KOR 5DS and KOR 6DT end mills now feature KCSM15A grade technology for improved milling performance
- **Turret Adapted Clamping Units (TACU):** Expanded connection options that provide greater compatibility across a wider range of machine tool brands

Together, these products are designed to improve process reliability, extend tool life and increase productivity while addressing the evolving demands of modern machining operations.

Kennametal Inc. | kennametal.com





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CloudNC AI-Assisted CAM Software Accelerates CNC Programming

CloudNC's CAM Assist solution, which uses AI to generate machining strategies for 3 and 3+2 axis CNC machines, is now available for GibbsCAM users.

The software is available as an AI-enabled add-on for GibbsCAM. The integration is designed to enable GibbsCAM users to program tool paths and machine parts more efficiently within their familiar CAM workflow.

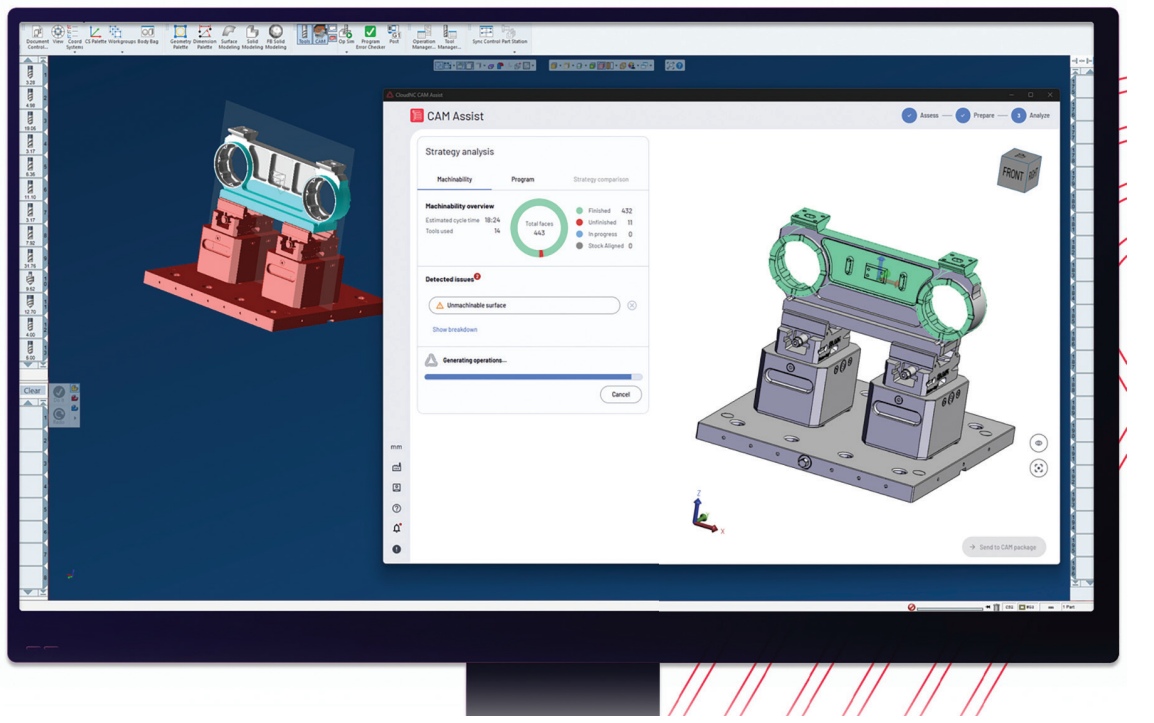
CAM Assist uses advanced computer science techniques and AI to generate machining strategies in minutes or seconds, depending on complexity — tasks that could otherwise take programmers hours or days to complete manually. According to the company, this reduces programming time, a common bottleneck in many factories, and also shortens the time required to estimate the cost of programming new components. That gain is said to enable manufacturers to raise productivity, shorten lead times and estimate for more work more quickly.

GibbsCAM users can also access CAM Assist 2.0, which combines AI-powered toolpath generation with step-by-step oversight. The upgrade allows programmers to configure machines, materials and tool assemblies, assess parts before running, review AI suggestions as they are made, and use the Strategy Editor to inspect, adjust and approve machining strategies before they are sent back into GibbsCAM.

"GibbsCAM is a powerful fit for machine shops that want a smart, flexible CAM solution that can scale from day-to-day production work to produce complex components," says Theo Saville, CEO and co-founder at CloudNC. "Bringing CAM Assist to GibbsCAM helps those users go even faster, meaning programmers can spend less time on repetitive toolpath creation, stay firmly in control of the process and focus more of their expertise on getting high-quality parts out of the door."

Thorsten Strauss, president of GibbsCAM, says the integration brings AI technology directly into existing workflows. "This collaboration with CloudNC enables programmers to automate repetitive programming tasks, accelerate part programming, and focus their expertise where it delivers the greatest value — all while maintaining full control of the machining process."

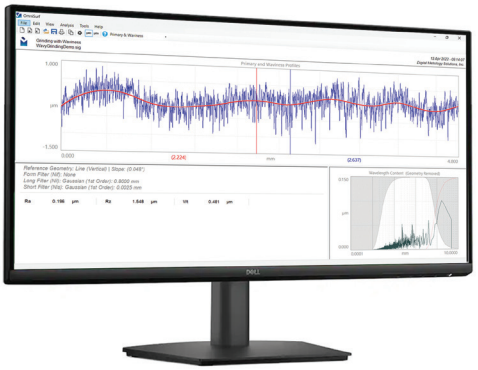
CloudNC | cloudnc.com
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Digital Metrology Surface Analysis Software Expands Analytical Tools for Engineers, Designers

Digital Metrology Solutions' OmniSurf surface profile analysis software is a visual software which provides an easy-to-use toolkit for exploring surface data for a wide range of users and applications.

OmniSurf 5.0 is designed to bring analysis out of the lab, enabling engineers and designers to explore surface data from measurement systems across product development, manufacturing processes and supply chains. Batch processing enables rapid analysis of data to quickly qualify processes and suppliers, and to discover root causes of production issues.



The OmniSurf 5.0 interface guides users through the analysis process, showing the effects of every analysis step. Tools have been added for preprocessing, geometry extraction and filtering. Hundreds of ISO 29210, ASME and function-specific parameters are now available to relate texture directly to performance.

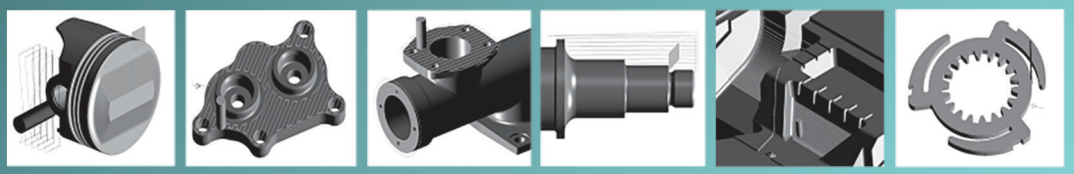
OmniSurf 5.0 also introduces several analytical tools not previously available in the platform. The wavelength content graph shows the shapes in data and allows users to interact directly with it and develop filtering specifications based on actual data. The macro wear tool quickly computes depths and volumes of wear scars, while the micro wear analysis measures microscopic amounts of wear without the need for accelerated testing. Morphological filters reveal voids where leaks could occur and highlight sharp features that could lead to cracking, penetration points in an oil film and similar conditions.

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CHRIS PASION | MANAGING EDITOR | cpasion@gardner.media

SPOTLIGHT | Additive Manufacturing

Mastrex Metal 3D Printer Supports Industrial AM Accessibility



Mastrex's MX300 industrial metal 3D printer is engineered to support manufacturers requiring precision, scalability and dependable production performance across demanding applications.

Built on laser powder bed fusion (LPBF) technology, the MX300 is designed to bridge the gap between prototyping and full-scale metal part production. The system combines a 300 × 300 × 350 mm build volume with dual 500W lasers, enabling faster production speeds while maintaining the accuracy and surface quality required for industrial manufacturing.

The MX300 is compatible with titanium, stainless steel, aluminum, cobalt-chrome, Inconel and more. The system is engineered to handle both detailed geometries and larger industrial applications while maintaining dimensional accuracy and repeatability.

The MX300 is designed for manufacturers and machine shops engaged in new product development, manufacturing of complex components and investigating new applications, particularly in the aerospace, defense and medical markets. These sectors continue to demand access to advanced technologies and materials to meet the requirements of critical applications and shorter lead times.

The MX300 also focuses on operational efficiency. Its high-throughput architecture and streamlined workflow are designed to simplify production environments and reduce downtime, helping manufacturers integrate metal additive manufacturing more effectively into existing operations.

As demand for industrial metal additive manufacturing continues to grow, manufacturers are increasingly looking for systems capable of delivering reliable production performance without unnecessary complexity. The MX300 was developed with that balance in mind, offering industrial-scale capability in a platform designed for long-term production use.

| Mastrex | mastrex.com

Phillips Large-Format 3D Printer Improves Production Flexibility

Phillips Corp.'s M1 Metal AM system from MX3D is designed for large-scale metal production. The M1 is said to provide an alternative approach to producing and restoring large metal components while reducing material waste and improving production flexibility. For mold builders and tooling manufacturers, large-format additive manufacturing offers opportunities to streamline repair workflows, reduce lead times for large tooling structures and castings, and explore new approaches to complex metal fabrication. It also enables new pathways for casting replacement, particularly for large, low-volume components where traditional casting may be cost-prohibitive or involve long lead times.

By producing components closer to final geometry, manufacturers can minimize excessive material removal and reduce machining time on large or difficult-to-manufacture parts. The M1 also supports repair and remanufacturing applications where rebuilding worn or damaged areas may be more efficient than replacing an entire component.



As additive manufacturing adoption continues to evolve across tooling and industrial markets, Phillips says it is focused on helping manufacturers evaluate where additive and subtractive manufacturing can work together to improve efficiency and expand manufacturing capabilities.

| Phillips Corp. | phillipscorp.com

DN Solutions Hybrid Platform Combines AM With CNC Machining in Single Workflow

DN Solutions' AM2CNC platform integrates additive manufacturing and CNC machining in a single workflow. The AM2CNC platform is designed to carry the workpiece from additive preform to qualified part inside one workflow, under one vendor with no integration gap.

An example of DN Solutions' AM2CNC in use is with the DLX 450 and the DVF 5000. The DLX 450 builds the preform; palletized automation delivers the stored parts directly to the DVF 5000, where the five-axis mill performs the high-precision finishing and tapping that turn a raw preform into a finished part.

The DLX 450 is a high-productivity laser powder bed fusion (LPBF) platform engineered for industrial-scale additive manufacturing. Its 450 × 450 × 470 mm (17.7" × 17.7" × 18.5") build chamber and up to four Yb fiber lasers — scanning at speeds up to 7 m/s — provide high build rates with stable, repeatable quality.

The DVF 5000 is a compact five-axis VMC engineered for lights-out automation and intricate workpiece geometries. Spindles up to 20,000 rpm provide up to 230 Nm of torque for demanding applications, and the AWC keeps the machine cutting through unmanned, continuous operation — finishing preforms around the clock.



According to DN Solutions, additive manufacturing creates the geometry, but cannot alone hold the dimensional accuracy and surface finish that defense, aerospace and medical parts demand. AM2CNC applies precision CNC finishing to complete what additive cannot, closing the loop from preform to certified, ready-to-use part. Because no two preforms leave the build chamber identical, AM2CNC measures each one directly in the machine and fits the finishing program to where that specific part actually sits, so the toolpath references the real preform on the table rather than an idealized nominal.

DN Solutions America | dn-solutions.us

EOS Metal 3D Printer Enables High-Volume Production

EOS' M4 Onyx is an industrial metal 3D printer for high-volume production. The EOS M4 Onyx combines productivity, automation and process stability to provide consistent, high-quality parts for demanding industries such as aerospace, defense, energy, semiconductor manufacturing and more.



The EOS M4 Onyx features six 400-W fiber lasers and a large 450 × 450 × 400 mm build volume, enabling higher productivity while reducing cost per part. Advanced process controls, optimized gas flow and active temperature management are designed to promote repeatable builds and part quality across the entire build platform.

To support efficient serial production, the system includes automated job changeovers in less than 30 minutes, increasing machine uptime and reducing production interruptions. EOS' RFS Pro filtration technology is said to improve operational efficiency by eliminating filter consumables, reducing hazardous waste and enabling more than 90% powder recovery.

EOS | eos.info

Modern Equipment Review

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Ingersoll Machine Tools and Innse-Berardi Platform Targets Faster Machining of Complex Aerospace Workpieces

Ingersoll Machine Tools and Innse-Berardi, sister companies within the Camozzi Group, introduce the IBPMax S machining platform designed for high-performance machining of large, structural aluminum aerospace components.

Developed to meet the competitive demands of aerospace manufacturers, the IBPMax S has been engineered to combine structural rigidity, dynamic performance and long-term machining accuracy within a single integrated platform. The machine is designed to handle large, complex aluminum structural components faster while maintaining precision and repeatability. The platform features the Tabm E three-axis head designed to offer high productivity, accessibility and machining flexibility.

Rather than functioning as a standalone component, the IBPMax S platform and the multiaxis Tabm E head have been engineered together as a fully integrated solution, allowing manufacturers to reduce machining times while maintaining process stability and accuracy.

The machine combines two key technologies said to significantly reduce machining time:

- Dynamic performance designed to enable full utilization of available spindle power during high-material-removal operations, maximizing productivity in roughing applications.
- A newly developed ABC head with advanced kinematics, enabling multiaxis machining with minimal angular movements, reducing finishing cycle times while promoting outstanding accuracy and surface quality.



The compact design and optimized inclination of the head also improve accessibility inside deep pockets and complex geometries, reducing repositioning requirements and enabling faster, more efficient machining of aerospace structural components.

Ingersoll Machine Tools Inc. | ingersoll.com

Starrag Five-Axis Enables Precise Single-Setup Manufacturing

Starrag's Bumotec 171 is a compact, high-precision five-axis machining center designed to provide exceptional productivity, precision and efficiency for manufacturers of complex, high-value components.

The Bumotec 171 combines advanced machining capabilities, intelligent automation and a compact footprint. Designed for complete part production in a single setup, it is well suited for manufacturing orthopedic implants, surgical instruments, minimally invasive medical devices, bone fixation components and other precision medical parts.

The Bumotec 171 enables complete machining from barstock to finished component in one machine. Its simultaneous five-axis configuration enables manufacturers to machine all six sides of a part while minimizing secondary operations, reducing handling, improving surface quality and shortening production cycles.

The machine's cast-iron construction supports rigid, accurate performance in a compact footprint.

To maximize productivity and machine availability, the Bumotec 171 incorporates intelligent tool monitoring capabilities that automatically detect tool wear or breakage and replace the affected tool with a backup tool from the magazine without interrupting production. Predictive maintenance functions, simplified machine access and a user-friendly FANUC control platform support efficient day-to-day operation and changeovers.

With capacity for up to 60 tools and an optional secondary operation unit, the machine provides the flexibility required for a broad range of complex, high-precision applications.

While optimized for medical technology, the Bumotec 171 is also well suited for aerospace, defense, micromechanics, optics, precision instrumentation, connector production and other high-value industries.



Starrag USA Inc.
starrag.com

Index Turn-Mill Supports Single-Setup Machining of Small, Complex Parts

Index Corp.'s G160 five-axis turn-mill is designed for single-setup machining of small parts of high complexity. An extension of the company's G Series family of turn-mills, the G160 offers a wide variety of options that allow it to be tailored to a mix of production requirements.

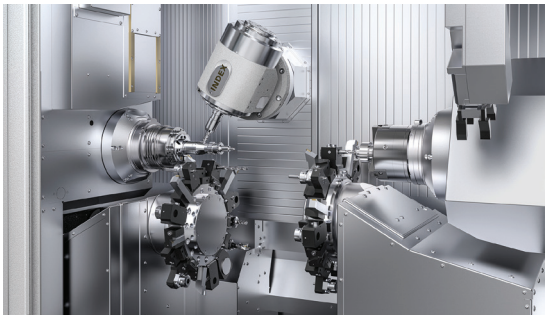
Built on a rigid, vibration-damping machine bed, the G160 incorporates a pair of highly dynamic direct-drive spindles, available with bar clearances of 1.64" (42 mm) or 2.56" (65 mm). Well suited for small parts, the 1.64" version provides 47.9 ft-lbs (65 Nm) of torque with a maximum speed of 7,000 rpm. Accommodating chucked parts to a diameter of 6.9", the 2.56" version provides 125.4 ft-lbs (170 Nm) of torque with a maximum speed of 6,000 rpm. Both options feature main and counter spindles of identical design, with an additional Z-axis on the counter spindle.

Providing the ability for full five-axis machining, the G160 includes an upper tool carrier with a B-axis and a direct-drive milling spindle matched to the turning spindles. The milling spindle features an HSK-T40 interface and offers 12.5 ft-lbs (17 Nm) of torque with a top speed of 32,000 rpm for the smaller option or 21.4 ft-lbs (29 Nm) of torque with a top speed of 18,000 rpm for the larger one. Tool magazines are available in 60- or 90-tool capacity, with a double gripper that automatically changes tools for the milling spindle.

Twin lower turrets can serve either turning spindle. Both turrets contain 15 stations with a VDI 25 interface, each of which offers a maximum speed of 7,200 rpm and torque of 13.6 lb-ft (18.5 Nm) at 25% DC.

The G160 features a Siemens Sinumerik One, a digital-native CNC optimized for highly productive machine tools.

The G160 is designed to facilitate unmanned production. A Unimag 5 interface enables connection to an Index Mbl 76 bar loader as well as to third-party equipment. For part transfer, customers can choose between a linear unit and conveyor belt, Index's integrated workpiece handling unit (WHU), or the Index Ixcenter robotic cell with palletized storage. The Ixcenter can also incorporate downstream processes such as cleaning, measurement and deburring. The G160 can additionally be equipped with a laser measurement solution to provide non-contact detection of geometric changes and cutting edge wear on the tools.



The design of the G160 is intended to provide energy efficiency. The machine's high acceleration and rapid traverse rates are said to eliminate up to 50% of energy consumption by reducing peripheral operating times. During operation, energy is recovered during braking, and intelligent material pairings and coatings lower friction to minimize both energy usage and wear on the machine. Spring-based counterbalancing reduces energy demands of the servomotors for vertical feed axes.

Index Corp. | index-group.com

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Jeff Norgord, Executive Vice President, Audience and Media Marketing

HOW I MADE IT

Cameron Weiss

Founder and CEO, Weiss Watch Co.

A fascination with watches took Cameron Weiss to Switzerland, but a desire to make them brought him back to the U.S. to start Weiss Watch Co.

INTERVIEWED BY | **JULIA HIDER**

I was always fascinated by watches as a kid. I liked anything mechanical. I was also interested in cars, but watches were more reasonable for me to play around with because they're much smaller.

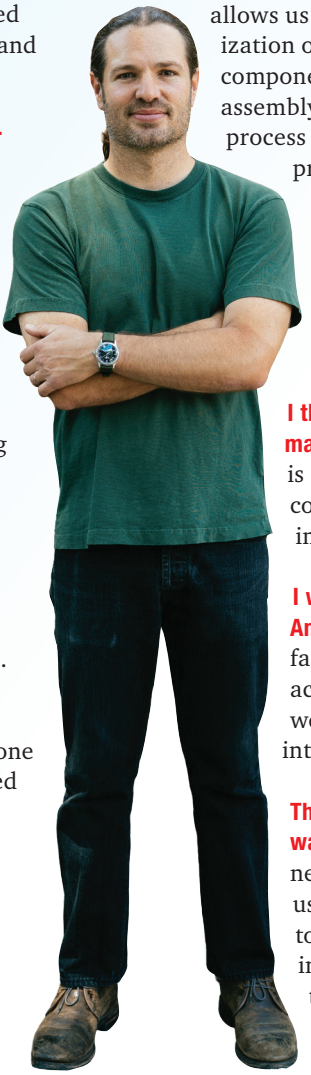
I attended a watchmaking school, a two-year, full-time program. It's a Swiss curriculum that is recognized by the Swiss industry called WOSTEP — Watchmakers of Switzerland Training and Educational Program.

After I graduated, I got a job working for Audemars Piguet. And then I got a job working for Vacheron Constantine and trained in even more complex watches, all mechanical. And then I started Weiss.

I was interested in manufacturing even before getting the watchmaking certificate. I wanted to actually be making watch parts, not just repairing or assembling watches.

With such a tiny assembly of so many parts, the tolerances have to be very small. They're usually 1 to 5 microns. It can become a bit of an issue, not only making the part but also measuring it. You can't even get calipers on a lot of them and there's certainly no CMMs operating on this scale. A lot of it is done with special microscopes or specialized fittings on calipers and micrometers.

We are making the screws and the pinions and the wheels and the plates and bridges that go in the movement, as well as the case and the crown and the buckles.



We have two collections. Our American Issue line is built using components manufactured in our Nashville workshop, reflecting the hands-on, small-scale approach that defines Weiss. Our Standard Issue line combines components machined in both Switzerland and Nashville, with final assembly completed in Nashville. That allows us to leverage the scale and specialization of the Swiss supply chain for certain components while maintaining our own assembly, regulation and quality control process in-house. The result is greater production flexibility without compromising the character of the watches.

We do some watch work for other companies. I have also done some research and development in medical devices. We're 95% focused on Weiss.

I think micromachining is the future of manufacturing. Just because something is small doesn't mean that it doesn't cost a lot. These are high-value, very important parts.

I would like to grow the awareness around American watchmaking, especially the fact that there are people in the U.S. actually making watches. And I really would like to see more young people interested in manufacturing.

There's a lot of emotion attached to a watch. It's an item that isn't really necessary. It's completely emotional for us at this point, so it's the perfect item to bring back to the U.S. manufacturing-wise. Just the fact that it's made in the U.S. makes it different.

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