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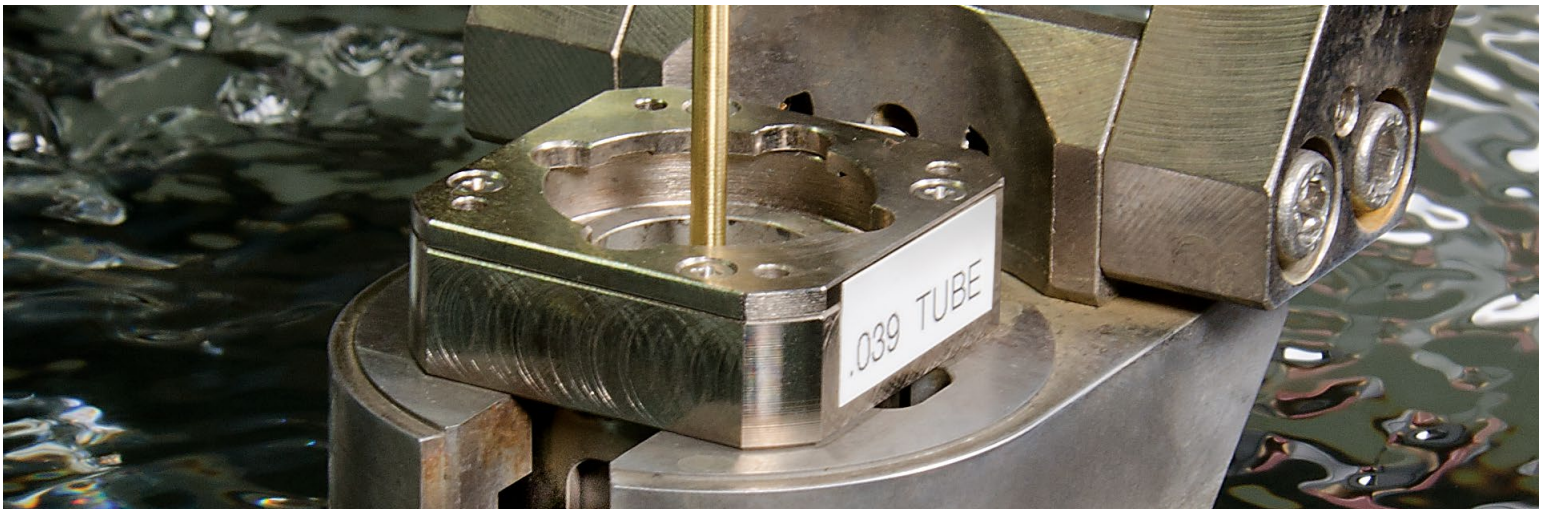

ON THE HORIZON

MARCH 23, 2017

Webinar: Breaking Through the CNC Barrier

Have you or someone you know ever spent hours on a CNC control proving out a part, debugging a program or even creating a program? Sometimes the only barrier between an idea and finished product is the CNC interface. Learn about the critical features and qualities of a CNC that can either help or hinder your productivity, profitability and even safety. Discover how Makino's Professional 6 control overcomes common CNC challenges by enabling operators to move fluidly through machine setup, easily access valuable information and benefit from safety enhancements. Break through the CNC barrier, and get your shop moving from parts to profits faster.

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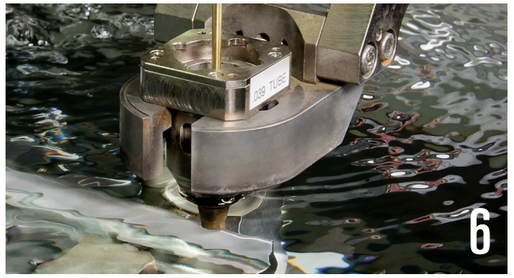
CONTENT

VOLUME 14.1



Q&A

WHAT ADVANCEMENTS MAKE DIFFICULT TITANIUM MACHINING FASTER AND MORE PRECISE?

In this question-and-answer session with Brian List, applications engineer at Makino, we take a detailed look at developments that adapt titanium processing to achieve these results:

- Enable deeper axial cutting
- Ensure excellent chip clearance
- Cut closer to finished forms using 5-axis toolpaths during roughing
- Mitigate heat generation with proper cooling and lubrication

Q: WHAT DEVELOPMENTS IN MACHINING TECHNOLOGIES AND CUTTING STRATEGIES SHOULD I BE AWARE OF TO SIMPLIFY TITANIUM MACHINING?

A: Through years of research and development, the machine-tool industry has learned a great deal about the machining characteristics of titanium. Today, manufacturers no longer need to rely on trial-and-error processing techniques. We have specialized machines, tooling, work holding and other accessories designed specifically for the job, and they are quite effective solutions at that.

The cornerstone of efficient and profitable titanium machining is employing a machine tool that has been built specifically for the job. This was the primary directive for the development of Makino's T-Series machining centers. Some of the characteristics found in these machines include high-power, high-torque spindles, extremely rigid casting structures, high-pressure, high-volume coolant systems for effective cooling and chip evacuation, and a multi-axis configuration that enables operators to perform roughing processes that interpolate offset from the final finished shape of the part. Together, these technologies dramatically reduce machining passes and extend the tool life and speed of the finish process by eliminating steps and extra material left by a traditional roughing process.

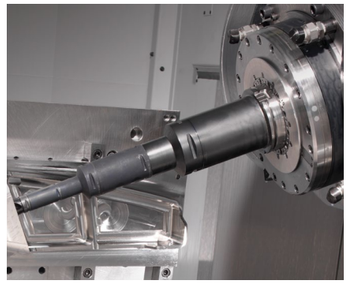
Complementing the development of these purpose-built machine technologies, engineers have also invested thousands of hours into the testing and analysis of new titanium cutting strategies. Such tactics include a thorough comprehension of cutting forces, chip thickness, radial engagement and how each of these impact tool life. By evaluating these cutting conditions, we've been able to better understand and control programs in relation to tool engagement and surface speed to achieve a highly profitable balance between productivity and tool life that exceeds previous limitations.

Q: IF TORQUE IS A KEY COMPONENT TO MACHINING TITANIUM, WHY NOT FOCUS ON INCREASING MACHINE TORQUE EVEN FURTHER?

A: Torque is certainly a critical factor in the machining of titanium, which is why the Makino T-Series machines incorporate 1,000Nm (787 ft-lbs) spindles. However, all components of a machine tool are interconnected in some way, which means all components of a machine must be up to the tasks of controlling or eliminating the vibration incurred from high-torque machining of titanium.

Manufacturers should be cautious as they evaluate machines with exceptionally high levels of torque. There are many machine builders on the market that have repurposed existing general-purpose machine platforms by simply cranking up the torque. As a result, the machines experience significant vibration when increasing tool engagement due to an imbalance in the machine design.

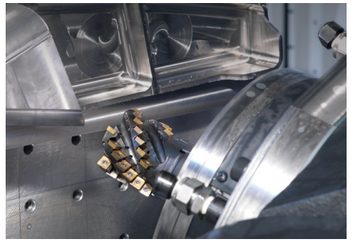
So, while high levels of torque are certainly necessary for efficient cutting of titanium, a machine's design must be rebalanced to accommodate more aggressive cutting forces.



Q: TO AVOID THESE VIBRATION ISSUES, WHAT TYPES OF MACHINE DESIGNS AND TECHNOLOGIES SHOULD I SEEK?

A: When it comes to machining titanium, traditional vibration solutions are no longer valid. Reducing and eliminating vibration in titanium processes requires machine stiffness and rigidity, vibration damping characteristics and specialized CNC software responses.

The primary and most critical feature is the innate stiffness and rigidity of the machine design. This can be a difficult attribute to evaluate on many machines, but there are some key characteristics



that manufacturers should look out for. These features include massive bed castings, wide, solid column designs, box guideway systems and large-diameter ballscrews. Combined, these characteristics can reduce the magnitude of deflection, damping out most vibration issues.

Another, less tangible means for reducing vibration is the use of CNC software. An example of this is Active Damping technology, a proprietary technology developed by Makino that takes an active role during processing to counter the development of vibration.

Q: ONCE I'VE IDENTIFIED AN APPROPRIATE MACHINE PLATFORM, HOW ELSE CAN I IMPROVE PRODUCTIVE CAPABILITIES? IS AUTOMATION A VIABLE OPTION?

A: If you've properly identified a rigid, stable machine platform that is up to the task of titanium machining, the key to further improving productivity lies in optimizing cutting processes:

- Provide a reliable process to reduce the amount of labor required to monitor machines, freeing operators to work on higher-value projects.
- Combine 5- and 6-axis capabilities with roughing and finishing on the same machine to slash costs associated with part handling.
- Eliminate post-machining blending and polishing activities by producing high-quality finishes.

Different forms of automation can also make a dynamic impact on productivity. For instance, Makino's T-Series titanium machining centers come standard with automatic pallet changers to minimize downtime during part changeovers. The machines can also be easily integrated into Makino's MMC2 automated pallet-handling systems, providing automatic pallet transfers, loading and production scheduling for improved flexibility.

Q: WHAT TOOLING TECHNOLOGIES HAVE BEEN DEVELOPED SPECIFICALLY FOR TITANIUM THAT SUPPORT THESE NEW MACHINE TECHNOLOGIES?

A: Historically, many manufacturers have used high-speed steel cutters to compensate for the vibration that would result from machining titanium on general-purpose machine platforms. Steel cutters are highly resistant to damage even when encountering recutting of chips and other unpredictable issues. However, these tools demand lower cutting speeds, which limits productivity and profitability. Recent advancements made on the machine side have yielded more flexibility in tool selection. Today, lab testing suggests that carbide-based tools with sharp cutting edges and high-relief angles tend to achieve the longest tool life, but in the field, these tools can also be highly susceptible to chipping and cracking when vibration occurs.

This takes us back to the importance of designing a purpose-built machine platform that reduces and eliminates vibration. By investing in a stiff, damped and actively monitored machine, such as Makino's T-Series machines, manufacturers are able to mitigate tool damage and achieve the maximum benefits of their tooling. The more rigid the machine platform, the greater the tooling flexibility.

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INVESTING TO GROW WITH CUSTOMERS, TURBINE TECHNOLOGIES PARTNERS WITH MAKINO FOR

HIGH-PERFORMANCE EDM

You're now in charge of a 50-year-old machine shop that by all accounts successfully served the aerospace and industrial gas turbine industries.

Your dad built up the business to include 80 employees making blades, vanes and other critical turbine parts on 100 electrical discharge machines (EDM). You spent every summer since you were 12 years old looking up to your father and preparing for this day by working in every department and learning how to operate the sinker EDMs.

So what do your biggest customers say soon after you assume leadership of the company?

They need partners with more advanced manufacturing capabilities. They expect suppliers to locate closer to their assembly plants in other states. What's more, the OEMs want assurances that your business is prepared to help them take advantage of the global expansion of both the aerospace and power-generation markets by increasing production, improving quality and speeding up delivery. Tyler Burke, a career military officer who retired to succeed his father as president and CEO of Turbine Technologies Inc. in Farmington, Conn., quickly sized up the new mission.

"There are a lot of mom-and-pops or Fred-in-the-shed shops, and the OEMs were very clear. They said there's going to be a washing-out period and you're either going to innovate, you're either going to invest or you're going to be rationalized," Burke said. "We made the decision to invest, to innovate and to find new ways to support our customers."

The conversations with Turbine Technologies' customers led Burke and his new management team to launch an expansion of their own. First, they invested in high-performance sinker, hole-drilling and wire EDM machines from Makino in 2015 in their existing shop in Connecticut. They then set up a second shop in Greenville, S.C., in 2016, outfitting it with additional Makino EDM machines and devising new manufacturing processes.

"Turbine Technologies was a very good legacy company, producing legacy components made on legacy machinery. We are remaking what has been a profitable company for new opportunities. That's what the

industry is asking us to do," Burke said. "It's the new products and the new machinery that make the business case work for us both on the technology side and financially."

CHALLENGE: HOW TO GROW A MATURE BUSINESS

In 2013, Burke assumed ownership of Turbine Technologies from his father, Robert. Robert is an engineer and entrepreneur with more than 50 years of experience in aerospace and defense manufacturing, and remains a board member and principal adviser to the company.

Turbine Technologies produces components for commercial and military applications, typically requiring machining to create profiles and cooling holes in turbine blades and vanes. While the older EDMs in Turbine Technologies' Connecticut shop still can make parts that meet legacy customer requirements, the company was not equipped to grow with its customers' expansion plans.

"It's important that we manage the company for long-term growth and stability. That's discussed nearly every day between my father and me," Burke said.

The gap between the company's capabilities and customers' changing requirements led Burke and his new management team to study the latest EDM technology, evaluate machine-tool builders, and spend much of 2014 planning how to invest to win new business opportunities.

A key consideration: Burke wanted an EDM platform that prepares Turbine Technologies to automate operations and enables the company to integrate individual machines into manufacturing cells and connect the machines to other business or production systems.

> "It was important to us to know that our machine supplier was spending significant capital on R&D."

In short, Turbine Technologies' leaders want to participate in the fourth, or next, industrial revolution. Burke intends to not be left behind as machine-tool technology and manufacturing software become networked cyber-physical production systems in the burgeoning Industrial Internet of Things (IIoT).

"We needed to partner with an EDM machine-tool manufacturer that had these similar values in mind and that is offering a platform that is going to be relevant into the future. It was important to us to know that our machine supplier was spending significant capital on R&D," Burke said.

Those requirements led Turbine Technologies to choose Makino as its sole supplier for EDM machines and select SST for consumables.

"A combination of factors put Makino at the top of our list. They have machines that are automation capable. Their technology and its ability to make shaped holes or diffusers at high speeds is a must-have, and their Hyper-i controllers are also a big reason why we invested in Makino," Burke said. "The fourth industrial revolution is about removing barriers between people and machines. With the Hyper-i control's interface and touch screen, Makino has a machine for the future."

UPDATING TECHNOLOGY FOR HIGH PERFORMANCE

Nearly all manufacturing operations at Turbine Technologies involve an EDM process. In 2015, the company started by updating its existing 40,000-square-foot Connecticut site with two EDBV3 EDM hole-drilling machines and a larger EDBV8 model—machines specifically designed for the production of cooling holes and diffuser shapes within blades and vanes for the aerospace and power-generation applications.

The machines feature a unique tooling system that integrates both automatic tool change and guide changing into one common assembly that can be quickly exchanged within 30 seconds. The EDBV machines include an integrated 2-axis rotary table for 5-axis positioning required in blade and vane machining. Additional features for high-efficiency EDM hole drilling include preprogrammed cycles for diffuser shapes, intelligent electrode length management, and internal water quality and temperature control systems.

The EDBV machines employ a 1,000-rpm rotating spindle with high-pressure flushing, and can produce holes down to 0.008 inches (0.200mm) in diameter. To aid in the reliable performance of small-diameter hole drilling, an automatic middle guide arm supports the pipe electrode during operation and prevents whipping or bending of the electrode.

Both the EDB3 and EDBV8 feature innovative Makino technology that prevents internal workpiece back-striking, and is capable of detecting breakthrough within one second, or 0.040 inches of depth. Such technology ensures quality-control measures and airflow are critical for proper cooling of the part.

"We're not paid for nonconforming material," Burke said. "We want to make sure that the part, when it goes out, will meet all of the customer's quality

The Hyper-i control provides a unified, intuitive interface for all Makino EDM machines and feature-rich database for testing or troubleshooting programming.

characteristics and expectations. The expectation at Turbine Technologies is every single part counts. We do not have a culture where it is acceptable to have scrap parts."

To achieve that goal, Turbine Technologies employees take a customer's requirements and set their own higher target for tolerances and surface quality. If a customer asks for cooling holes in a nickel alloy shroud with a true position of no more than 20 thousandths, Turbine Technologies will find a way to drill the holes with a true position of 10 thousandths.

About to come online are two more EDBV3s and two EDAF2 sinker EDM machines that integrate the dielectric reservoir into the base casting of the machine, which reduces floor-space requirements while improving thermal stability.

Some of the company's EDM machines date back to the 1960s, but remain in production for legacy aerospace and industrial gas turbine parts. The commodity EDM machines throughout Turbine Technologies' Connecticut shop each require an operator. All of the Makino machines are equipped with an ATC (automatic tool changer) and standardized pneumatic work-holding fixtures to extend unattended operation. In a new Makino EDM cell, four machines are operated by one employee who loads and unloads parts while a second employee cleans and inspects the parts. The machines can be loaded and unloaded by robots, making further automation possible in order to expand production capacity when the company and customers are ready.

> "The expectation at Turbine Technologies is every single part counts. We do not have a culture where it is acceptable to have scrap parts."

Graphite electrodes for the EDAF2s and the company's legacy sinker EDMs are now being made on a Makino F3 VMC (vertical machining center). The graphite machining center, added in late 2016 and outfitted with a rotary axis table, provides stiffness and rigidity for chatter-free cutting, agility for high-speed, hard milling and accuracies for tight-tolerance blends and matches typical of complex, 3-D contoured geometry. Because the F3 is fully enclosed and attached to an air filtration system, graphite dust is now collected, removing it from the machine envelope and improving air quality throughout the shop, which was impossible when using the company's older open-commodity mills to machine electrodes.

Also featured in the F3 is Makino's proprietary SGI geometric intelligence software—developed specifically for high-feedrate, tight-tolerance machining of complex, 3-D contoured shapes involving continuous, tiny blocks of NC data. The SGI software is designed to deliver and ensure production rates faster than standard CNC systems while maintaining high accuracy and smoother geometry blending. Tool maker Vern Hussey, a machinist with 35 years of experience, said he now programs the F3 to easily cut a radius that previously required manual benchwork because the company's commodity mills could not accurately produce the feature.

Productivity in the Connecticut shop also is projected to be improved for jobs requiring larger parts by an investment in a Makino U1310 wire EDM, which provides support and rigidity for workpieces weighing up to 13,228 pounds (6,000 kg). Cycle-time improvement is significant.

Makino's proprietary H.E.A.T. technology, which uses two independent CNC-controlled flush pumps to dramatically improve flushing efficiency, reduces cycle time and wire consumption. The U1310 also enables Turbine Technologies to consistently achieve a surface quality of 20Ra for the part—far exceeding the customer's

requirement of 80Ra, engineering technician Jary Dzierlatka said. The combination of capability allows Turbine Technologies to produce parts faster and with greater accuracy and higher quality levels.

Working with the aerospace engineering team from Makino and SST, Turbine Technologies expects to continue to improve programming to lower the cycle time for the shrouds, Lamprey said.

EDM technology have quickly learned to run the Makino machines because the Hyper-i provides simple-to-follow fingertip controls. Machining procedures and how-to videos are immediately available for each setting and process,

> "We have seven new parts in development. It's a huge timesaver being able to step up to the Hyper-i to set up and test the programming right on the control."

Since 2015, Turbine Technologies has made significant investments in Makino machinery to help fuel innovation and meet new OEM requirements for speed, quality and cost.

so the operator does not need to walk away from the 24-inch control screen. Engineers who do not operate the machines on a regular basis can easily use the Hyper-i control to test or troubleshoot programming, as well as develop processes for new applications.

"I never have to question whether I can do something with these machines. We have to spend months dialing in settings on the older machines. With the Hyper-i control, we are dialed in the first time. We're up and cutting quickly. We have seven new parts in development. It's a huge timesaver being able to step up to the Hyper-i to set up and test the programming right on the control," Lamprey said.

NEW SHOP FOR NEW OPPORTUNITIES

In South Carolina, the 28,000-square-foot Greenville shop houses over a half dozen new Makino EDAF3 sinker EDMs located across the aisle from even more recently purchased high-speed-hole EDMs. The commodity machines were certified for production of an aerospace turbine shroud, which requires a complex hook-shaped feature.

"In side-by-side testing, burning the hook shape into the nickel alloy is significantly reduced on the EDAF3s, the cycle time has been reduced while also extending electrode life from four parts per electrode to 16 parts," engineering manager Justin Lamprey said.

Also in South Carolina, Turbine Technologies invested in two EDBV8s and several smaller EDBV3s for drilling cooling holes in the shrouds, some with diameters as small as 60 thousandths.

All but one of the new machines feature Makino's new Hyper-i control, a unified control system for all Makino EDM machines that provides intuitive, intelligent and interactive functions with the touch-screen functionality of smartphones and tablets. This familiar but powerful and user-friendly interface is one critical reason Turbine Technologies chose Makino as its machine-tool manufacturer. Operators experienced on the company's older

MAKING WHAT'S PROMISED ON TIME

What matters most to the leaders of Turbine Technologies is delivering high-quality aerospace and industrial gas turbine parts to customers on time and with zero defects. Partnering with Makino and SST to engineer new EDM solutions that make the most efficient use of the company's investment in advanced sinker, wire and hole-drilling technology is a central part of Turbine Technologies' growth strategy.

Since implementation of the machines in both Connecticut and South

continues on page 28

TURBINE TECHNOLOGIES GROWS WITH VETERANS

A CONVERSATION WITH **TYLER BURKE**

Tyler Burke learned a lot about leadership while serving as an Army tank commander in Iraq, and operations officer in Afghanistan. But the most important lessons came not on the battlefield but from civil engineering projects, including the rehabilitation of sewers and municipal trash service in Baghdad.

"Being able to, at the drop of a hat, change your mission, learn a new set of skills and do it at a high level is very important in the military; and it has become a part of our culture within the company," Burke said.

Burke is a veteran of two wartime deployments to the Middle East, and 20 years split between active duty in the 1st Armored Division and the Vermont Army National Guard. He retired from the service after he took over as CEO and president of Turbine Technologies; yet the military continues to shape Burke and the ways he leads his company. The management team includes veterans who run operations at Turbine Technologies' manufacturing facilities in Farmington, Conn., and Greenville, S.C. One of the vice presidents, John Guyette, retired after 30 years in the Vermont Army National Guard. He had been commander of the Army's Mountain Warfare School. Burke served under him in Afghanistan.

Veterans now comprise 20 percent of the company's employees in Connecticut and 40 percent in South Carolina.

"We use the planning, staffing and organizational models that we learned in the military," Burke said. "We've adapted them into and integrate them into the Turbine Technologies dialogue and methodology. By bringing the military guys in, we can easily adapt, and it's a quicker understanding of our goals. It's our lexicon. It's easier to learn. We stick with what we know."

The military influence shows up throughout the company and starts with the hiring process. While military service is not a requirement for job candidates, Burke enjoys working with veterans because they share a universal language and set of values that influence the overall company culture. This reduces the time it takes for new employees to learn about the company and procedures, Burke said. When Army combat veteran "Ms. Shim" was hired, she immediately found an environment where her experience as a CH-47 Chinook helicopter mechanic and crew chief in Afghanistan could be immediately applied as Turbine Technologies' facilities and maintenance manager.

> "The military values and structure directly translate into a competitive edge in the management of the company."

"When we hire a veteran, we all know the Army values. There are seven values: loyalty, duty, respect, selfless service, honor, integrity and personal courage. We hire for that character and then train the talent," Burke said. "The military values and structure directly translate into a competitive edge in the management of the company."

That does not mean that Burke and his senior leaders issue commands or that machinists and office staff stand at attention and salute when supervisors enter a room. Employees are expected to do more than follow orders. Central to the military model is that all participants identify challenges, recommend multiple courses of actions, evaluate which action will result in the best outcome, and then implement that action.

"It's not an overly regimented organization is what we're saying, 'like it's my way or the highway,'" Burke said. "When the engineering manager brings me an engineering issue I'm not familiar with, I'm going to follow his guidance on the best course of action. I'm here to ensure the customer has what they need by leveraging the best people with the best skills with the best resources. That's how the military gets the job done. That's how we get the job done."

View additional video content at radical-departures.net/Triumph

ADVANCED MACHINING TECHNOLOGY

HOW TRIUMPH STRUCTURES INCREASES PRODUCTIVITY

What matters most to the leaders of Triumph Structures–Wichita is keeping the aerospace components manufacturer on the leading edge of machining technology in order to meet customers' requirements for quality and on-time delivery.

But when you're making monolithic structural parts for commercial and military aircraft, few machines are big enough for the job. That's why the company invested in the first Makino A6 in the United States. With this 5-axis horizontal machining center in production since July, Triumph has exceeded its goals in three ways:

"With the combination of the MMC2 and MAG3 machines, we're able to run large aluminum parts 24/7 with an overall equipment effectiveness of 85 percent."

- Lowered cycle times by more than 50 percent for aluminum parts previously processed on a gantry-style vertical machining center

- Reduced part changeover and setup times from hours to minutes on some applications, thanks to the duel automatic pallet changers on the A6

- Increased peak metal removal from 80 cubic inches per minute to more than 500 cubic inches per minute in some applications

"We strive to be a world-class facility. We want to not only deliver on time with good quality, but we also intend to be world class through our processes and the way we cut aerospace structural parts. In order to do that, we obviously need to have world-class equipment to support that dream," said Kelly Eilerts, applications manager for Triumph Structures–Wichita.

BIG PARTS, BIG CHALLENGES

Triumph Structures–Wichita is a division of Triumph Group, a global leader in manufacturing and overhauling aerospace structures, systems and components. In Wichita, Kan., Triumph makes a variety of jet aircraft and helicopter parts, and transports them to other Triumph facilities for subassembly before delivery to original equipment manufacturers (OEMs).

Triumph makes complex aerospace parts out of titanium and aluminum. Some of the billets start out as large as 3,000 pounds and 17 feet long. To machine such massive workpieces, the company continues to invest with Makino. By the middle of 2017, there will be 18 Makino machines, including the A6, three T2 5-axis horizontal machining centers for landing-gear trunnions and other hard-metal parts, and 14 MAG3 5-axis horizontal machining centers for high-productivity machining of aluminum aerospace parts.

The T2 machines enable Triumph to machine titanium and steel parts at a cutting feedrate of up to 630 inches per minute. They are able to efficiently mill titanium as a result of several advanced technologies, including an active damping system, rigid construction for enhanced performance, a high-torque, high-powered spindle, and a high-pressure, high-volume coolant system for increased speed and productivity. A third T2 is being relocated from another Triumph facility to grow the company's titanium capabilities in Wichita.

The 14 MAG3 machines, including both standard and MAG3.EX versions, run at 33,000 rpm to machine wing ribs, wing spars, bulkheads, floor panels and stringers. An additional five MAG3 machines are also planning to be moved from another Triumph facility and installed within a Makino MMC2 pallet-handling system to create a cell dedicated to wing ribs.

"With the combination of the MMC2 and MAG3 machines, we're able to run large aluminum parts 24/7 with an overall equipment effectiveness [OEE] of 85 percent," Eilerts said.

Equipped with Makino's advanced Professional control system, the A6 can be programmed to automatically shuttle pallet loads for unattended operation.

The combination of automated pallet-handling systems and 14 MAG3 5-axis horizontals provide Triumph with uninterrupted production of wing ribs, wing spars, bulkheads, floor panels and stringers.

For the largest wing skins, spars and ribs, however, Triumph had previously relied on a gantry-style vertical mill. While capable of producing parts that meet OEM requirements, the machine limited the company's ability to grow with the booming aerospace industry. Specifically, Triumph needed better thermal stabilization to improve precision. The gantry-style machine is enclosed by four walls, but has no roof on its cabinet and thus no climate controls, exposing the spindle, tools and workpieces to temperature changes in the shop. With programs scaled to account for temperature variation, the process is slow and operators must take multiple temperature readings before, during and after processing.

In addition, the gantry-style machine has no external workstation for setting up pallets or means of changing tools automatically. The spindle must be stopped each time a tool is replaced or parts are loaded and unloaded, resulting in unproductive time. The operators must shut down production and work inside the machining envelope.

WHAT'S BEHIND ALL THAT POWER

While parts can be accurately produced on the gantry-style machine, it requires more time than a high-speed horizontal mill like the A6. The vertical spindle on the gantry-style machine turns at 25,000 rpm, powered by 80 horsepower. The A6, meanwhile, is equipped with a 33,000-rpm horizontal spindle, powered by 161 horsepower.

"This speed and power upgrade enables Triumph's operators to hog out metal on the structural parts in some cases as fast as 1,600 inches a minute," said Ricky Davis, director of operations at Triumph and a veteran of nearly 30 years at aerospace manufacturers in the Wichita area. "I've never seen a machine move that fast."

"This speed and power upgrade [of the A6] enables Triumph's operators to hog out metal on the structural parts in some cases as fast as 1,600 inches a minute."

To control thermal variation, which can affect tolerances, the A6 is equipped with its own HVAC system that pumps 45 tons of chilled air into the machine enclosure to keep the work envelope as well as the bed casting and the automatic tool changer at 68 degrees Fahrenheit. Coolant is automatically chilled or heated as needed to maintain a constant temperature in the spindle, tooling and workpieces.

"The gantry machine is much larger, but the temperature taken at the beginning of machining is not going to be the same as the temperature taken at the end of machining. That can introduce a lot of variables. Heat from the machine itself is added as it's moving. Coolant temperature changes. This affects the temperature of your part. With the A6, all of these variables have been

removed. That makes it much easier for us to machine large parts accurately and consistently without having to scale our programs," Eilerts said.

What really influenced Triumph's decision to invest in the A6, however, are the opportunities the machine creates to improve productivity.

The A6 is equipped with two worktables outside the machine. This design enables operators to set up pallets with any combination of jobs, which currently feature four versions of wing skins and spars for those wings, a wing rib and three versions of helicopter floor panels. Ergonomic worktables are lowered into a horizontal position to enable operators to safely and comfortably bolt and pin workpieces into position. Once setup is complete, the worktable is raised into a vertical position and is ready to be moved into the A6 just as soon as processing of another part finishes.

Triumph takes full advantage of this capability. The company runs two 12-hour shifts on weekdays, with one operator scheduled on the A6 during each shift. Before weekend shifts, jobs are set up in advance and are ready to be run by an operator who splits time on other machines on Saturdays and Sundays.

> "The parts coming off the A6 are in the 30Ra range or better, which is four times greater than what our customers require."

"That's where the multiple tables come in handy, because we are able to use our limited resources on a weekend to unload and reload a part while the machine is still running," said Nick Raffety, the lead A6 operator.

Equipped with an advanced Makino control, the A6 also can be programmed to automatically shuttle loaded pallets in and out of the machine, freeing up operators to handle other tasks. Triumph also equipped the A6 with Makino's MPmax software to monitor the machine's performance, including what programs it ran, cycle times, tool-change times and utilization rates. MPmax can alert operators and managers to issues or when it's time for a part change. This is just one way in which Triumph's team is continually learning and implementing new features to expand unattended operations.

HIGH SPEED—AND HIGH QUALITY

Investing in an advanced horizontal machining center with the capabilities of the A6 is a significant business decision. Triumph made the commitment in no small part because of the capacity the horizontal machining center adds to its Wichita facility. The company had one customer in mind

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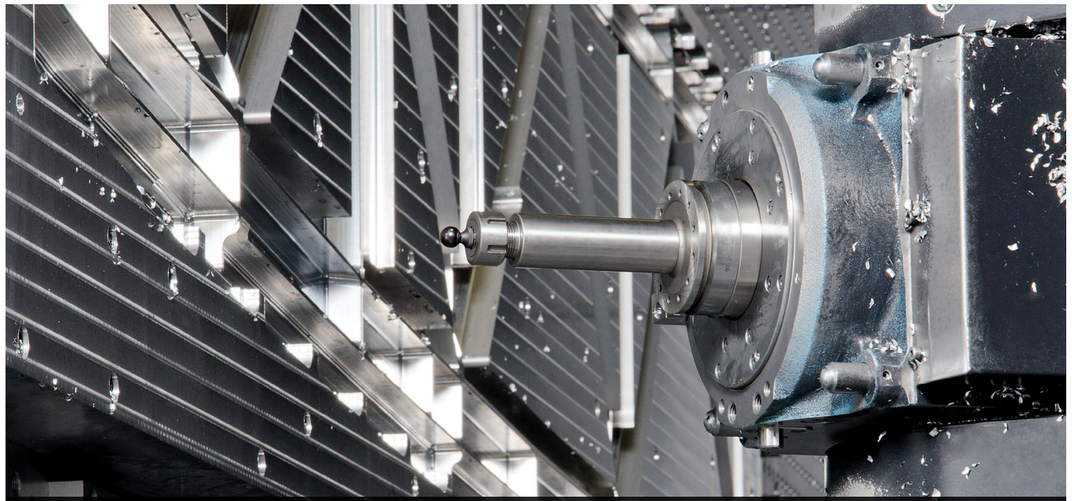


The 161-hp, 33,000-rpm spindle on the A6 has enabled Triumph to increase peak metal removal up to 1,600 inches per minute.

EDM HOLE-DRILLING TECHNOLOGY

FOR THE MOST DEMANDING TURBINE ENGINE REQUIREMENTS

By Brian Pfluger, EDM Product Line Manager, Makino

As aerospace manufacturers strive to improve engine performance and reduce fuel consumption, the need for advanced hole-drilling capabilities in electrical discharge machining (EDM) has grown substantially. New engines are being designed with special diffuser cooling film holes for improved airflow efficiency, along with special thermal coatings to raise the engine operating temperature to meet the requirements necessary for performance, fuel economy and component life.

Other industries increasingly are looking for more efficient small-hole manufacturing capabilities as well. Power-generation equipment manufacturers produce gas turbine engines with similar requirements to the aerospace field, but in larger components. As a result, the efficiency, quality and productivity of EDM drilling operations are critical in achieving proper airflow and engine component cooling. As many new turbine engine programs begin to enter and ramp-up for full production, suppliers throughout the manufacturing base are re-examining and investing in advanced EDM drilling technologies to gain greater throughput and improve efficiencies to meet the changing production demands.

DEMANDS UNIQUE TO BLADES AND VANES

Many cooling holes are simple, round holes concentrated on the leading or trailing edge of a component; however, more complex cooling-hole geometries, such as diffusers, feature tapered or funnel shapes that lead into a finished "through hole." These through hole and diffuser holes enhance airflow for cooling, and the diffuser hole shapes can have variations in geometry and depth on the same part. In addition, they are machined to blend into the complex 3-D shape of part detail.

Blade and vane components typically have a hollow interior for weight saving and internal airflow. During the EDM drilling process, the cooling film holes break into these internal cavities. To preserve the correct airflow, it is critical that no back-wall impingement, or back-striking, occurs during drilling.

Back-striking happens when the drilling electrode comes in contact with the opposite internal cavity wall, creating a hole or divot on the internal surface, which can cause disruptions in airflow and subsequently create a hot spot within the engine component.

Metallurgical quality is also an important concern. The most crucial characteristics are the recast (the re-adhered molten material) and heat-affected zone (altered microstructure and hardness area of the underlying base material), which could impact the operating life cycle of the component.

SELECTING THE IDEAL EDM HOLE-DRILLING SOLUTION

With a variety of EDM hole-drilling technologies available on the market, it is critical for manufacturers to understand the unique advantages and disadvantages of each machine, including oil- and water-based platforms. This type of evaluation typically begins with the nature of hole features required, including size, shape and quality.

In the case of cooling film holes for turbine engine blades and vanes, water-based EDM drilling machine platforms, such as Makino's EDBV-Series machines, are typically best suited based on their speed and productivity output. The EDBV-Series machines are configured with unique technologies that are ideally suited for turbine engine cooling film-hole production requirements:

- C-axis spindle rotating up to 1,000 rpm with a vibration-control finger mechanism helps to provide stable and consistent operation with full long-length electrodes.
- Fully integrated 2-axis rotary table supplies access to multiple areas of the workpiece.
- Fully submerged machining operation helps to improve EDM drilling speeds by up to 10 times that of conventional technologies, and eliminates overspray and slip hazards in the production environment.
- Programmable rise-and-fall work tank offers excellent open access to the work zone while supporting and simplifying automation integration.
- Proprietary, highly sensitive breakthrough detection circuit can sense cavity-wall breakthrough in just one second. That translates to breakthrough detection to within approximately 0.040 inches to 0.060 inches (1.0mm to 1.5mm) of machining depth.
- Automatic tool change (ATC) and automatic guide change (AGC) systems afford hours of unattended operation and programmable, automated capabilities for machining varying hole diameters. The complete tool exchange is also performed within 30 seconds.
- Achieve consistent metallurgical quality with recast and heat-affected zone (HAZ) levels of under 12 µm (0.0005 inches), using optimized speed settings.
- Standard water quality and thermal cooling systems include water filtration, water deionization to control conductivity, and a water chilling unit to maintain the water at the same temperature as the machine casting (improves accuracy and repeatability).
- Simplified canned cycle programming of cooling hole and diffuser hole machining is achieved on the intuitive and user-friendly Hyper-i control.

The EDBV-Series machines can also be applied to a variety of applications outside of aerospace, extending the value of the machines and giving manufacturers the opportunity to enter additional markets, such as energy and power generation. Manufacturers can also integrate these platforms within automated systems to achieve even greater productivity, faster return on investment and lower per-piece costs, further enhancing competitiveness.

Discover what type of EDM hole-drilling machine platform is best suited for your manufacturing operations in Makino's complimentary white paper, "Selecting the Appropriate EDM Technology for Hole-Drilling Applications."

Visit makino.com/whitepapers/EDMholedrilling.

TRANSFORM YOUR SHOP

INTO AN INTELLIGENT FACTORY WITH PRONETCONNEX

Makino's new ProNetConneX offers manufacturers a built-in, instant on-ramp to the Industrial Internet of Things (IIoT), with secure connectivity to today's leading business management systems via the MTConnect standard.

ProNetConneX provides the data and connectivity necessary for intelligent factories to rapidly respond to fluctuating market demands. As a machine interface, ProNetConneX connects and collects machine data in the MTConnect data standard format within a shop's network for use to improve productivity and efficiency.

Digital connectivity and integration are bringing manufacturing operations out from behind the curtains and into enterprise planning, scheduling and product life-cycle systems. Makino introduced ProNetConneX to provide simple and secure transmission of machine information across connected devices on the factory floor. Secure connectivity is achieved through Cisco's Connected Machines Solution with accessibility to today's leading software management systems via the MTConnect standard.

With machine monitoring and connectivity, ProNetConneX is able to integrate machine data within enterprise resource planning (ERP) systems in ways that enable business leaders to make better-informed decisions and control their manufacturing operations in real time.

INTEGRATED IN ADVANCED MACHINE CONTROLS

ProNetConneX facilitates the free-flow of machine data for intelligent factories with software built into Makino's machining centers. Capabilities are highlighted below:

- Real-time data collection and accessibility
- Machine health monitoring
- Cloud data collection either locally or via the internet
- Secure local network and cloud-based systems connectivity
- MTConnect v1.3 compliancy

Unlike other IIoT machine interfaces, ProNetConneX is fully integrated into Makino's latest machine controls. Additional machine sensors can be installed within machines and added to ProNetConneX to expand data-collection capabilities based on each shop's unique manufacturing needs.

COMPATIBILITY AND CONNECTIVITY VIA CISCO AND MTCONNECT

Makino engineers helped to develop MTConnect as the industry standard for communication between machines and devices on the factory floor. Compatibility with the latest MTConnect standards enables ProNetConneX to connect with a company's choice of business management systems.

ProNetConneX easily integrates with solutions from Memex, Scytec, Lemoine, Freedom eLog, Forcam and many other leading providers. For example, using ProNetConneX, machine data can be supplied to Forcam for part production monitoring, control and interfacing to MRP/ERP systems.

Data security and cloud services are enabled in cooperation with information technology (IT) leader Cisco. Developed to support industrial fog computing environments, Cisco's Connected Machines Solution enables rapid and repeatable machine connectivity for real-time data monitoring and management. ProNetConneX uses a Cisco Industrial Ethernet (IE) 4000 Series switch to stand up to the most abrasive environments and protect equipment and internal networks from security threats. This system provides a familiar platform for IT technicians to quickly and easily navigate network security settings.

MAXIMIZE PRODUCTIVITY WITH MPMAX

Also compatible with ProNetConneX is Makino MPmax, a real-time machine process monitoring and data-management solution. Developed to support manufacturers in optimizing machine processes, MPmax includes spindle load, speed and vibration monitoring analysis tools and capabilities not available in any other software platform.

When combined, ProNetConneX and MPmax enable manufacturers to optimize the efficiency of their manufacturing operations and get the most out of their machining investments.

To monitor critical processes across a variety of machine platforms, MPmax has data-management capabilities to track the following key machine performance indicators:

- Status monitoring
- Utilization monitoring
- Alarm analysis
- Spindle and axis monitoring
- Tool data management
- Probe data analysis
- Camera monitoring (optional)
- Power-consumption monitoring (optional)

VIEW THIS WEBINAR:

Learn more about Makino's ProNetConneX and other IIoT solutions in Makino's webinar:

- Onboarding to the Industrial Internet of Things

>> Go to makino.com/library

continued from page 16

when considering the investment and selecting the A6 to make wing skins and wing spars for a specific commercial platform. But Triumph now uses the A6 for so much more. In the first four months of production on the A6, the company has been able to move additional parts from the slower gantry-style machine onto the A6, as well as win new commercial and military orders. Faster cycle times that result from the speed and power of the A6, in addition to productivity gains from having two pallets, are key.

"We're able to do things so much faster than we anticipated that we've put ourselves in a position to realize a full return on investment within just a few years and faster than we had planned," Eilerts said.

Some of the faster production can be attributed to the machine control on the A6. Most of Triumph's T2 and MAG3 machines use the same type of control system, making it easy for operators to quickly learn how to run the A6 without extensive training. Triumph also has standardized 121 tools in the A6's ATC, and collaborated with Makino's aerospace engineering team to revise and standardize programming. With Makino's engineers, Triumph focused on developing new machining methods and manufacturing processes to make full use of the A6's features. The result is not just speed but also precision and quality, with repeatable tolerances of plus or minus 0.0001 inch and surface finishes of 32Ra. The need for secondary finishing has been reduced as a result.

"The parts coming off the A6 are in the 30Ra range or better, which is four times greater than what our customers require. It's very impressive to hold that kind of surface finish with the feeds and speeds we're running at," Eilerts said.

Triumph's investments in T2 5-axis horizontal machining centers have enabled the company to machine titanium and steel parts with feedrates of up to 630 inches per minute.

"We're able to do things so much faster than we anticipated that we've put ourselves in a position to realize a full return on investment within just a few years and faster than we had planned."

Because of this combination of speed, precision, repeatability and high quality, the A6 enables Triumph to expand its relationships with customers and to also pursue new customers. The A6 keeps Triumph Structures–Wichita right where its leaders want to be—on the cutting edge of manufacturing technology and learning new ways to make better aerospace structural parts that cost less.

"We're still proving out our processes and parts, but we have a lot of parts we could run on the A6 and reduce our cycle times by 40 to 50 percent," Davis said. "We're just getting started." Triumph is now planning its next step with Makino.

FAST AND ACCURATE

MAKINO'S LARGEST NX-SERIES MACHINING CENTER DELIVERS FOR AEROSPACE MANUFACTURERS

The **Makino a120nx horizontal machining center** delivers high speed and accuracy while also handling oversized structural components for the aerospace industry.

To mechanically support the unique challenges of big workpiece processes, Makino employs the proven designs of its other nx-Series machines, such as three-point leveling and a tiered column design. Aerospace manufacturers are sure to find the a120nx more than able to meet their needs. **The a120nx features:**

- Vast X-, Y- and Z-axis travels of 74.8 inches, 63 inches and 66.9 inches (1900mm, 1600mm and 1700mm, respectively)
- Standard large pallet size of 39.4 inches by 39.4 inches provides capacity for parts weighing up to 11,000 pounds
- An automatic pallet changer switches from one pallet to the next in 38 seconds, minimizing non-cut times for the highest levels of productivity
- Storage for up to 204 tools up to 35.4 inches long, 14 inches in diameter and weighing up to 77 pounds
- Maximum cutting feedrates and rapid rates for all linear axes of 2,126 inches (54 meters) per minute

BUILT FOR RIGID CONTINUOUS PRODUCTION

Makino uses its three-point supported bed casting as the foundation for the a120nx. Makino's design ensures all points are stable and contacting the floor. Developed to maintain the machine geometry and alignments, this design characteristic of the nx-Series machines simplifies installation and enables easy relocation of the machine.

Building on the rigidity of the bed casting, the a120nx incorporates a unique tiered column design that delivers greater resistance to Z-axis cutting forces throughout the work envelope. Robust cross-roller-style B-axis table bearings work in concert with a high-force rotary clamping system to ensure stable cutting throughout the machine's expansive work zone.

Superior workpiece clamping is attributed to Makino's four-cone pallet location and clamping system that delivers a secure 46,500 pounds of force on the pallet. This superior clamping capability combined with all pallets built to a master pallet eliminates deflection. Other standard features include an engineered precision air-blow system that cleans locating surfaces as well as pallet clamp confirmation.

ENSURE IDEAL GEOMETRY AND ACCURACY

Machining large aerospace parts requires producing larger features, too. Tool length, diameter and weight capacities of the a120nx support processes that use large face mills, boring bars and line-bar tooling.

The a120nx includes systems to manage the heat generated by rapid traverse of 2,126 inches per minute. The ballscrews are core cooled in all axes to yield consistent accuracy during continuous production. The ballscrews are all dual supported and pre-tensioned to ensure unparalleled dynamic positioning repeatability.

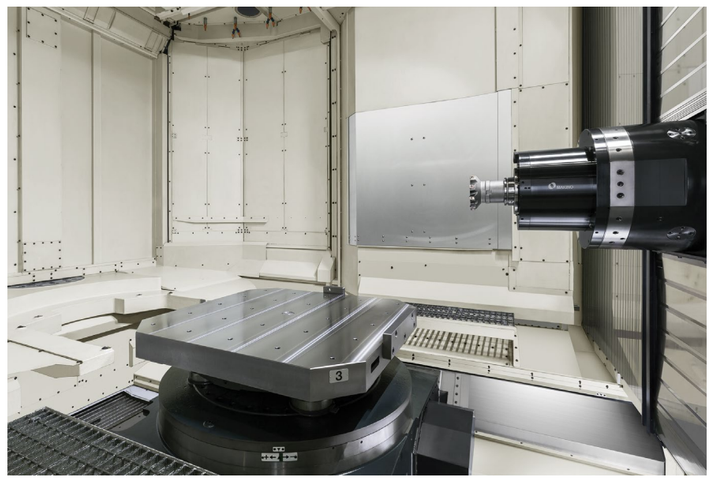
In addition, feature-to-feature movement distances on large parts are typically much greater, so rapid traverse rates were increased for the a120nx to cover these distances quickly.

POWERFUL SPINDLE OPTIONS, PALLET CLAMPING

The a120nx improves productivity in cutting and non-cutting performance.

The standard high-torque 8,000-rpm spindle boosts continuous power levels by significant levels over levels typically found in machines of this class. With 50 continuous (74 peak) horsepower, the spindle is ideally suited for heavy, high metal-removal-rate machining of ferrous and hard-metal materials. In addition, the spindle features impressive acceleration and deceleration capabilities due to its high duty-rated performance characteristics that serve to reduce rigid tapping times by measurable amounts.

Also available is an optional 18,000-rpm high-power spindle, ideally suited to high metal-removal-rate machining of light alloy structural components for aerospace components and semi-conductor manufacturing apparatus machining applications.



Within some machine-tool designs, the management of the machining byproducts is often overlooked to the point that they can result in interrupted operations, increased labor costs, machine damage, part-quality issues and reduced tool life. The Makino a120nx enables manufacturers to avoid these limitations with thoughtfully designed chip and coolant management features, including a combination of vertical and steeply sloped internal surfaces to remove obstacles between the workpiece and the machine's central chip trough, allowing for efficient chip flow out, to the rear-mounted, high-capacity lift-up conveyor. A standard cyclonic filtration system delivers ultra-clean coolant to the through-spindle coolant pump.

ADVANCED CONTROLS, AUTOMATION READY

The a120nx is an agile heavyweight that comes with Makino's Fanuc-based Pro-6 CNC control, which features a user-friendly touch-screen interface and advanced tool data management. Also included as standard is Makino's patented Geometric Intelligence high-speed machining control system.

As more manufacturers look to increase productivity, reduce labor costs and compete successfully in the global marketplace, it's critical that machining centers be designed to work in cells with robotic workpiece handling systems, as well as other types of automation solutions. The a120nx is fully compatible with Makino's versatile multi-machine, multi-pallet MMC2 flexible manufacturing system and its highly capable MAS-A5 cell controller.

Discover more about the productive benefits of the a120nx in large aerospace part manufacturing at **www.makino.com/a120nx.**

ACHIEVE 95 PERCENT SPINDLE UTILIZATION

ON THE a61nx-5E 5-AXIS HMC WITH THE UPDATED MMC2

When OEM requirements call for faster delivery of small batch orders and reduced per-piece part costs, aerospace manufacturers of all sizes can successfully compete by automating machining operations. The Makino Machining Complex (MMC2) automated material-handling system has recently been updated to help aerospace suppliers achieve these goals with enhanced multi-axis processing flexibility.

The updated MMC2 retains the same modular design and capabilities of its predecessors, but with a new pallet-transfer interface on the system's rail-guided vehicle (RGV). This interface is able to handle the unique pallet designs used on Makino's popular a61nx-5E 5-axis horizontal machining center. As a result, manufacturers are able to achieve spindle utilization rates upwards of 95 percent to further maximize the value of their a61nx-5E investment. Together, this system gives aerospace manufacturers more control of their workflow and the ability to adapt quickly to customers' just-in-time needs for complex, multi-dimension part applications.

"Based on feedback from current a61nx-5E owners, we'd come to realize that the machine's productive capabilities were so high that most operators were struggling to keep their machines fed with raw materials," said David Ward, product marketing manager at Makino. "While we see this as a good problem to have, it is still an issue that we wanted to address. By providing this optional pallet interface on the MMC2, we're able to help manufacturers keep up with the productivity rates of the a61nx-5E to get the most value out of their investments."

CAPACITY TO MEET THROUGHPUT DEMAND

The MMC2 is designed to accommodate up to 15 machining centers and four work-setting stations into a single system. Each system is able to hold up to 200 pallet stockers—stacked either one, two or three layers high—with a virtually unlimited variety of parts and fixtures.

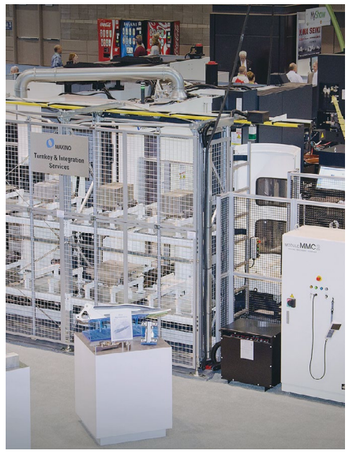
The system's RGV is supported by a floor rail and upper-guide rail for enhanced stability and simultaneous, high-speed movement. The system's work-setting stations (WSS) provide easy access for operators to load and unload parts either by hand or crane. Each WSS has 180-degree pivoting doors to save space and prevent a cluttered work area. The MMC2 can be equipped with optional workpiece washing guns.

Users of the MMC2 frequently report spindle utilization rate improvements of up to 95 percent, leading to dramatic increases in production without adding staff or equipment. The MMC2 system permits users to virtually eliminate part setup time, reducing non-value-added time in their machining operations. By providing a continual flow of parts to the a61nx-5E, the system can run for extended periods unattended, including overnight and on weekends.

ADVANCED SOFTWARE CONTROL

The updated MMC2 retains Makino's state-of-the-art cell control software, the Makino Advanced System-A5 (MAS-A5). This Microsoft Windows-based software maximizes production output while monitoring multi-machine production requirements. The MAS-A5 main PC hard drive stores and manages all NC programs for optimum machine utilization, including NC programs that exceed CNC memory.

In addition to NC programming, tool data, both in and out of the a61nx-5E machines, can be accessed and modified from the MAS-A5 user interface. A variety of tooling and part information file formats are supported and can be displayed to assist with part loading/unloading



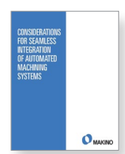
and tool-setting operations. A Tool-Life Predict function enables the MAS-A5 to gather tool-life data per NC program. It informs the operator of how long a tool is used in each NC program execution and how many spare tools are required in order to finish the current NC program. The MAS-A5 schedules work only for machines that meet tool-life and availability requirements for the desired process sequence. Interfacing with a tool presetter also reduces errors by automatically capturing tool-offset data, which can be transferred from the presetter to the MAS-A5 system control.

The MAS-A5 maintains all processing steps required to complete a part. The system automatically schedules work-setting and machining operations according to the defined part process sequences, recognizing material and machine availability. Intermediate work-setting operations can be included in a process sequence to allow for setup changes. For more complex processing requirements, the MAS-A5 enables multiple jobs to be assigned for each machining process.

With the MAS-A5, there is practically no limit to the number of fixtures and associated process sequences and offsets that can be logically assigned to an individual pallet. Using material availability and user-assigned priorities, the software automatically allocates work to each fixture.

The MAS-A5 manages and schedules production orders for each part defined and lets the operator input a production start date and due date. Work can be scheduled dynamically using priorities set for pallets, process sequences and production orders as well as for multiple other methods. System priorities can be easily reassigned to meet changes in schedule or demand. The MAS-A5 also includes a production order capacity check that evaluates all orders and part quantities required and necessary cycle times. In addition, a chart displays system capacity on a daily basis.

Several built-in reports are included with the cell controller, such as production data, tool data, results, alarm history and utilization. Alarm notifications can be configured to be automatically generated and sent via email. Custom report writing is also available.



Looking to automate your aerospace manufacturing systems? Download Makino's white paper, "Considerations for Seamless Integration of Automated Machining Systems," to find out what considerations should be made before acquisition.

Visit makino.com/whitepapers/integration.

MAKINO

continued from page 10

Carolina, Makino and SST engineers and technicians are promptly available by phone and email and in person whenever needed to assist Turbine Technologies as its team plans how to produce parts now in development.

Turbine Technologies' new F3 with graphite package has enabled the company to reduce electrode production times by up to 84 percent for complex, 3-D contoured geometries.

"Our customers want to see their hardware conforming to specified requirements, that we get it to them on time, and with cost alignment. We are able to do that because the Makino machines have operated exactly as they were promised to us," said John Guyette, vice president of operations for Turbine Technologies in South Carolina.