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Aerospace Machining Solves Challenges Big and Small

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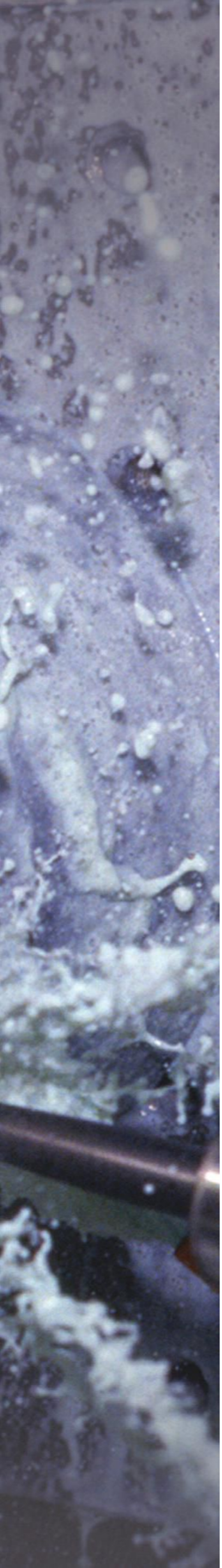

Aerospace Machining Solves Challenges Big and Small

From machining monolithic parts for airplane wings to turning small jet engine parts, machining continues to advance the art of creating better, more affordable parts.

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Contributing Editor

A blisk, such as the one being machined here on a Mitsui Seiki machine, is a good example of the complexity, amount of material removal, and volume of coolant often involved in aerospace part applications. (Provided by Mitsui Seiki)

Aerospace machining encompasses machines small and large. These range from the Tornos SwissNano to the Makino MAG3, as Rich Sullivan put it. He is the OEM manager for Iscar Metals Inc., Arlington, Texas. The first machine has a footprint under 8 sq. ft. (0.74 sq. m) and makes parts under 4 mm in diameter. The latter could put eight SwissNanos on the pallet.

Yet for any size part, cutting tool and machine tool suppliers are developing technology to make those parts faster and better. The challenge for users is finding a machine that meets tomorrow's needs as well as today's.

MRR vs. Tight Tolerances

Aerospace manufacturers have two fundamental conflicts: increasing material removal rates (MRR) while meeting tighter tolerances. That is the perspective of Scott Walker, chairman of machine tool builder Mitsui Seiki (USA), Franklin Lakes, N.J. The need for high MRR is obvious when considering large aircraft structural parts. But even small Swiss-turn type parts often need tough machines and tools.

Brian Such, vice president of customer support for Swiss machine builder Marubeni Citizen Cincom Inc.

Allendale, N.J. said the "most common fact" in aerospace machining is the use of corrosion-resistant materials. Materials like Hastelloy, Waspaloy, and MP35N, all of which have "high chrome characteristics and high tensile strength," he said. "These parts require very rigid machine setups and rigid cutting methods. A cheap machine will quickly fail with these materials!"

What's more, tolerances are tight. Parts are expensive. Aerospace manufacturers want to keep scrap to a minimum. Maintaining a stable, predictable process that produces a perfect part every time is a virtual religion in aerospace.

But Walker cautioned that some machines that deliver high MRR "don't lend themselves to those rates on a long-term basis." Likewise, he said, some machines achieve required tolerances over a short period of time, but then the machine settles in and can drift on certain features on tight-tolerance parts. "As a result, they really don't have a robust process for either tight-tolerance parts or for the high MRR applications for an extended period of time."

Also, Walker said OEMs "have to make a part for 20-plus years. A Tier 1 or Tier 2 supplier may sign a 10- or 20-year agreement. Some have 40-year agreements. We're seeing a lot of customers potentially putting themselves at long-term risk because they're looking at a machine that's capable today, but they're not determining if it's going to be capable for the long-term."

As Walker explained, the end user needs to gamble on a machine that makes the part for a relatively short-term program or invest in something that lasts for years and can repurpose at the end of the program—a long-term asset that delivers both precision and high MRR means stiffness, rigidity, torque, and thrust. But, Walker added, it is not as simple as comparing numbers in a brochure.

Just because a spindle has a certain horsepower and delivers a certain torque, it may not do so in the speed range required.

"You really need to analyze the spindle characteristics. And when you get into really heavy cutting, the spindle might be adequate but do the motors driving your linear and rotary axes also have sufficient torque to perform the operation? It all needs to work together," he said. Walker added that the machine must adequately handle the harmonics created in the anticipated operating range.

But he also pointed out that excessive vibration sometimes occurs at lower than ideal operating speeds. The counter-intuitive solution is to run harder and faster to find the sweet spot. Finally, he suggested prospective buyers consider a machine builder's reputation in meeting tolerances and MRRs. Examine what machines the OEMs and their suppliers are using for the same applications. "A machine is usually aimed at doing tight tolerance work or it's capable of high MRRs, but not necessarily both. With Mitsui, you can have both for a very long period of time," said Walker.

Citizen's low-frequency vibration technology oscillates the Z axis while cutting to consistently break chips. (Provided by Marubeni Citizen-Cincom)

Trends and Technology

Aerospace machine tools appear to be on the cusp of big changes. Walker suggested machines are becoming more specialized for certain high-volume areas like aerospace-grade aluminum. Here you want high-horsepower, high-torque, high-speed machines that "just remove an incredible amount of material but aren't well suited for cutting titanium or nickel alloys," according to Walker.

Caron Engineering's TMAC system can display multiple sensor channels at the same time, even on a handheld device. (Provided by Caron Engineering)

Although aerospace parts are typically low-volume, Walker said some programs present high-volume challenges. Boeing is making over 50 units of its 737 Max a month. "They're now setting up transfer lines and/or flexible manufacturing solutions to meet the larger volume of parts, because one-piece part flow in which you machine a part complete in one setup doesn't necessarily work when you have to make 100 of that particular component per month."

It is not just aluminum airframe components. Walker calculated that the 737 Max requires over 450 engine parts a month—parts that might need a 20 or 30 hour machining operation. "So automation is playing a much larger role in aerospace than it has in years past, even in the lower tier supply chain shops. That includes quick-change tooling, zero-point fixturing, and in-process inspection," he said.

Tom Chambers, regional representative-Southwest at Hainbuch America, Germantown, Wis., said industry is demanding higher end machines that include multi-axis, live tooling, and quick changeover capability. "Workholding is especially crucial in the demand for high precision and repeatability," he said. "Customers are using our precision workholding systems because they not only provide extremely high accuracies and repeatability, but also because they are designed for fast changeover—even from OD to ID parts. Repeatability is especially important when the emphasis is on speed and automation in production. For low-volume, short runs, flexibility is a primary consideration."

Sullivan from Iscar Metals said that "generally speaking, in aerospace machining you have to look for flexibility." He pointed to the trend toward additive manufacturing, hybrid machines, and multi-tasking mill-turn-grind machines. "You almost have to over-buy in this industry now because you can't design a process only for the part you have now," he said. Engineers need to future-proof the machine. "In my opinion, once aerospace starts diving into hybrid machines that combine additive and subtractive machining, it will open the floodgates, because there's a lot of money to be saved." Large OEMs are now making some aerospace engine parts by casting a relatively inexpensive material and then using hybrid machines to selectively apply Inconel. He also sees the line between parts traditionally milled vs. turned is becoming blurred.

In turning, Such of Marubeni Citizen-Cincom explained that "Swiss machines often need to take extreme depths of cut to get parts processed." But most cutting tools and machines can't handle these extremes. In some operations, the chip will not break, blocking critical coolant from the tool and destabilizing the process. So Citizen developed low-frequency vibration (LFV) technology that oscillates the Z axis while cutting. Such said the tiny movement is timed in sync with spindle rotation to consistently break the chips.

"There are programmable ways to make the tool enter and exit the cut repeatedly while cutting, and the programmer can still cut two-axis angles or radii with tool nose radius compensation, all with the exact same CNC code they've always used," he said. "Just turn LFV on and it's done. LFV is also great for axial drilling or live tool cross drilling. Both of these cuts can better perform while in Citizen LFV mode."

After-Market Solutions

Rob Caron and his team at Caron Engineering Inc. in Wells, Maine, have developed a suite of solutions for aerospace. Since aerospace manufacturers focus on achieving a stable process that minimizes scrap—and many aerospace materials are hard or abrasive—machinists tend to run conservatively. Caron created an adaptive control product that automatically makes continuous, real-time adjustments to the machine's feed rate as the tool moves through the material.

"This enables users to program more aggressive cuts knowing that if the tool will break or the material has some hardness anomalies, we'll automatically slow the tool down at that point," explained Caron.

The company's system, Tool Monitoring Adaptive Control (TMAC), is not just software. Nor does it rely on the machine's inherent torque sensing. Instead, Caron adds a "far more sensitive device for measuring cutting power than what the controls deliver. It's infinitely scalable and we can change the sensitivity on the fly based on what type of tool is cutting and how much it's cutting."

Interestingly, while Caron said a few machine tool builders resist the addition of TMAC, "the control guys are fine with it. Most of them really want it and come to us. The big guys, including FANUC, Siemens, and Okuma, want us to integrate."

For example, an OKK HMC equipped with a FANUC 310is-A control was profiling and scalloping the flange on a 718 Inconel jet engine case with a 1/2" (12.7 mm) end mill and assorted drills. Due to the varying cutting conditions, the feed rate had to be set to accommodate the worst material condition, resulting in a part cycle time of about 25 hours. After implementing TMAC, the shop reduced scallop milling time by 60 percent.

TMAC also looks at both tool vibration and bearing health. "By monitoring changes in the level of tool vibration in a cut, we can alert the user to problems," explained Caron.

Caron Engineering also offers ToolConnect, a system that adds RFID (radio frequency identification) capability to any machine. The typical approach would be to use a presetter to write tool data (to include the intended machine pocket for the tool) to an RFID chip on the tool holder. Then the Caron system reads the chip to not only transfer the proper data to the machine control but also to prevent the operator from putting the tool into the wrong pocket.

Caron Engineering offers software that uses finished part data to automatically feed offset adjustments based on the deviations between the measured values and the nominals. Caron said this "eliminates human error in typing in offsets, adjusting the wrong tool, or over-adjusting tools."

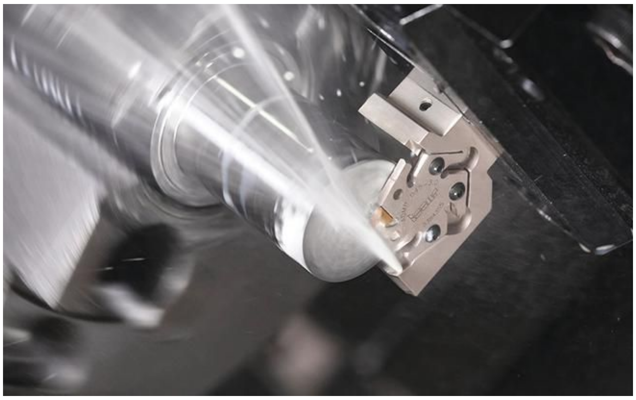
Improving Legacy Machines

Chambers said Hainbuch has also found a market with companies that are using its precision workholding systems on older machines, increasing their capabilities for complex and hard-to-machine parts. "By equipping a lower-cost or entry-level machine with precision systems, they can afford to compete for a wider range of aerospace parts," said Chambers.

Finally, there is strong agreement that, except for some composite materials, high-pressure coolant (up to 1,000 psi) is essential for maximizing throughput. Look to companies like ChipBlaster and MP Systems to add this capability to existing machines. Iscar's Sullivan praised a new feature that enables the machine control to tell such add-on pumps to change the coolant pressure for different cuts, as programmed. That is important, he explained, because some tooling is pressure sensitive. For example, one insert might work best at 600 psi while others cannot get enough.

Cutting Tool Considerations

Both Iscar Metals and Sandvik Coromant, Fair Lawn, N.J., focus on aerospace and both have placed a premium on delivering high-pressure coolant to the cutting zone. Scott Lewis, Sandvik Coromant's aerospace industry specialist, calls his company's concept "high-precision coolant." The toolholder includes nozzles that direct the coolant to exact locations on the cutting edge to optimize tool life and the performance and consistency of the tool. Lewis said coolant



High-pressure coolant is essential for optimum performance in many applications, as shown here with Iscar's LOGIQ5GRIP cut-off tool. (Provided by Iscar)

aids both heat and chip removal, depending on the shape of the insert. "Most of our holders have above and below coolant flows," he added.

Iscar's approach is similar in its LOGIQ turning and cut-off line. Sullivan explained that cut-off tools are by their nature susceptible to failure "so getting coolant to the tip of the cutting tool is a huge advantage and you need high pressure to do that." Sullivan also pointed to his company's LOGIQ drill line, which includes indexable, helical drills with screw-on heads that deliver coolant to the tip even up to 12xD.

Many in aerospace define and lock down manufacturing processes by various certifications. It is difficult to introduce improvements. However, tremendous demand is making the industry more open to changes. New projects offer an opportunity to explore new solutions with greater freedom. "Whether it's a new process or an improvement to an existing process," Lewis said, "our approach to offering a better solution is to address the complete package. It could be a new grade, toolholder, or toolpath."

Sandvik Coromant fields a team working in CAD/CAM that helps customers by suggesting new toolpaths in programs that would work better with the newer tools. "We can either consult with them or actually work hand-in-hand to change the machining program," explained Lewis. "As these customers lose a lot of experienced programmers, they look to tooling companies for our programming support, sometimes recommending changes, sometimes actually making the programs." Sandvik Coromant's Fair Lawn facility includes an Aerospace Applications Center equipped with state-of-the art machining centers. There the company tests customer parts, determining which tools, toolpaths, and cutting data work best.

While both Iscar and Sandvik Coromant offer a variety of standard tools, including both indexable and solid round tools in carbide, CBN, ceramic, and PCD, aerospace tools often need to be customized. That customization can include everything from modifications to the carbide grade to changes in the edge prep. Sandvik Coromant also offers a "tailor made" program that can change a standard tool's overall length, neck length, or other basic features for a specific application.

Another Sandvik Coromant service is its regular introduction of "component solutions," packages of mostly standard products for specific components. “Packages include toolpaths, cutting parameters, tool recommendations, and the tool life we experienced in our testing,” explained Lewis. So, for common parts, such as a blisk or a retaining ring, Sandvik Coromant offers standard tools and application guidelines for cutting standard features on those parts.

Lewis also highlighted vibration-dampening toolholders. “Sometimes [aerospace] needs a length that exceeds the diameter-to-length ratio prescribed for a basic turning bar or a basic milling adapter,” he explained. They may have to cut deep, or reach beyond a feature, such as in engine shafts. “You can play the game with different cutting parameters or insert geometries to improve the process but sometimes you can’t fix it without a dampened adapter or bar,” he said.

Sandvik Coromant offers dampening bars with embedded digital sensors, called SilentTools Plus, part of the CoroPlus suite of digital machining products. These tools have the same benefits as a standard dampening bar with the added benefit of communicating the bar’s performance to the machine or a handheld device. This provides constant feedback to the operator, represented graphically. The operator learns what level of vibration delivers a stable, chatter-free process and dials it in. The embedded sensors can measure vibration, whether or not the tool is in the cut, cutting forces, bar temperature, center height, and other factors.

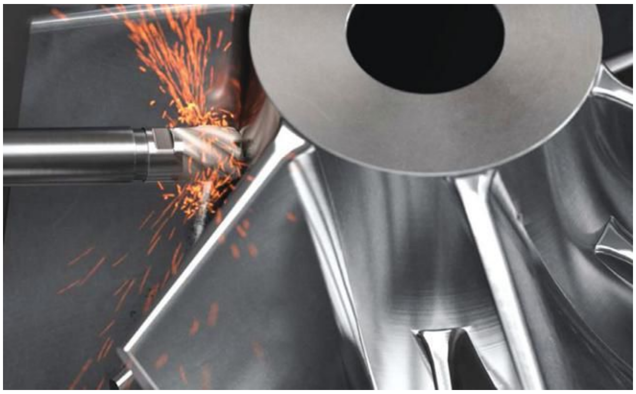
This technology is also coming out in fine boring tools. Lewis said the next step would be to use the machine control to use this data to make automatic adjustments in real time.

Sullivan said Iscar sees the need for reducing force “because the fixturing for some parts can be anemic. A lot of our solid-carbide tools use variable pitch and variable helix to break up the harmonics to allow us to run faster and smoother and not invoke as much force into the part.” He also highlighted Iscar’s Multi-Master line of tools. These tools attach a carbide screw-on head onto a solid-carbide, heavy metal, or steel shank.

“You get the benefit of the reach and the clearances of a solid-carbide tool without the expense," Sullivan explained. Finally, he said small-diameter indexable tools have been a focal point, with Iscar’s LOGIQ line drills going down to 4 mm in diameter and its two- and three-flute end mills down to 5/16 and 3/8" (7.9 and 9.5 mm) respectively.

Both Lewis and Sullivan pointed to jet engine builders’ penchant for developing their own proprietary materials as a significant challenge. “These materials are sometimes the most challenging because the OEMs are reluctant to provide samples or sufficient information about the material," said Lewis. "On the other hand, there are situations in which we work with the engine builder from the beginning and learn together about how best to machine the material.”

The introduction of additive and hybrid machining technology is heightening the challenge because, as Sullivan put it, “manufacturers can play with the metal powder almost in real time. You can know what the particles are and the percentages of the materials in the part. But the way the manufacturer mixes them and the way they bond is unique and it’s anyone’s guess as to how it’s going to cut.” No wonder Lewis joked that in the automotive industry, the question is “Can I make 1,000 parts with this tool?” In aerospace, the question is “Can I make it through this pass with this cutting edge?”



Solid round ceramic tools (here from Sandvik Coromant) are emerging as a solution for some challenging aerospace applications like this blisk. (Provided by Sandvik Coromant)

FYI

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