▶ BY BILL KENNEDY, CONTRIBUTING EDITOR

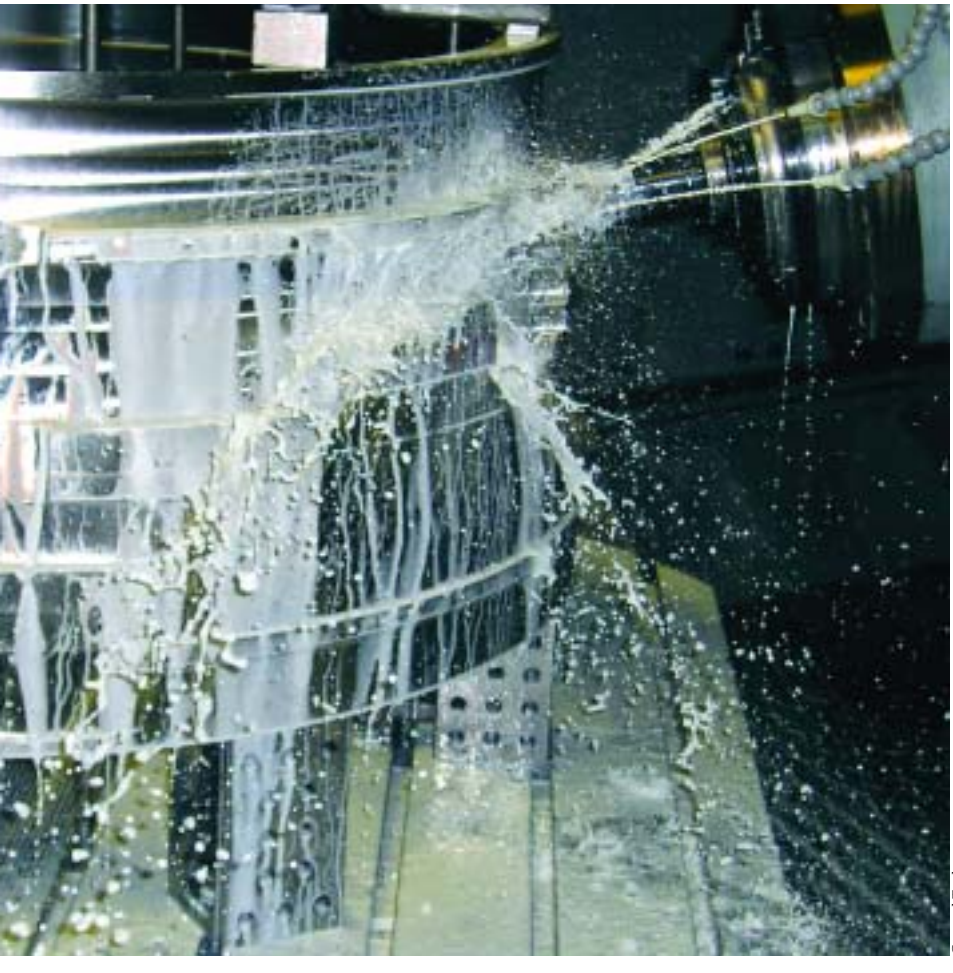
FLEX TIME

Versatile machine tools and creative strategies help shops handle high-variety, low-volume aerospace machining.

"Volume" is a relative term when it comes to manufacturing.

Scott Garbarino, COO of aerospace supplier Pacific Tool Inc., Redmond, Wash., said: "Talk to an automotive manufacturer and you don't get into volume until you get to a million units. In aerospace, it's in the hundreds. Low volume is five to 20."

Due to the nature of the business, aerospace manufacturers generally produce small numbers of a variety of parts—a traditional prescription for inefficiency.



General Tool

Aerospace shops are acquiring the advanced technology needed to produce small lots of high-quality parts. Shown is a titanium fan case produced at General Tool for an F110 jet engine.

John Goes, vice president of operations for machine tool distributor Ellison Machinery Northwest, Kent, Wash., said, "Many of us who grew up in industry were taught that manufacturing processes associated with large lot quantities are better. Our goal now is to break the relationship between unit cost and quantity and reach the utopian goal of an economic lot quantity of one part."

Though perhaps beyond their reach, aerospace manufacturers are finding ways to economically and competitively produce a wide variety of parts in lot sizes approaching one. They achieve this through careful deployment of advanced machine tool technology and innovative process strategies.

Trickle-Down Technology

The shape of the aerospace industry's supply chain is changing. As a result, the pressure—and the technology required—to efficiently produce small lots of high-quality parts is shifting to smaller shops.

Mark Waymouth, aerospace marketing manager for Makino Inc., Mason, Ohio, said: "The development of the

supply chain of aerospace, frankly, is very similar to that which has occurred with automotive. Automotive has a Tier 1 supply chain, a Tier 2 supply chain and so on. That same thing is happening in aerospace."

Prime contractors like The Boeing Co. outsource the manufacture of major components to suppliers such as Goodrich Corp., which, in turn, commission smaller companies to machine the components' individual parts. These shops face tough competition, both domestically and overseas, to submit the lowest possible bid and meet just-in-time production schedules. As a result, even the smallest of these subcontractors are seeking advanced equipment and other technologies that will enable them to efficiently machine a variety of parts in small lots.

Bob Albaugh, marketing specialist for machine tool builder Hurco Cos. Inc., Indianapolis, said the spread of high-tech machines to smaller shops is growing "as we go through the transition into outsourcing and people are getting their sea legs as suppliers." Initially, many smaller shops think advanced technology is too expensive.

"They think, 'I can't afford that,'" according to Albaugh, "but as they realize what they've got to do to remain competitive on a global basis, they're starting to see that they've got to move up to that next level. When they put the pencil to the paper and see what kind of time they can save, the light bulb goes on. They say, 'I've got to charge a hundred dollars per machine-hour for this work, but, wow, I can do it in one-third the time.'"

Albaugh said Hurco is responding to the demand for advanced technology by smaller manufacturing companies with machines like the VMX24S. It's equipped with a high-speed spindle that operates at higher rapid-traverse and feed rates. He pointed out that the company's UltiMax conversational programming system enables an operator to program a machine on the shop floor without needing to know G-code or macros.

Hurco

Hurco's VMX24S is designed to deliver advanced technology in a smaller package. Operating dimensions are 160"×145"×108". A 12.5-hp motor drives the 10,000-rpm spindle. Axes travels are 24"×20"×24" (X, Y and Z). The rapid-traverse rate is 1,181 ipm for the X and Y axes and 787 ipm for the Z.

Mono Machining

Trends in aerospace manufacturing methods are also fueling demand for 5-axis machining centers. Waymouth said Makino developed its MAG series of horizontal machine tools to permit high-speed machining of a five-sided, monolithic part from a single billet. Steady growth in this type of machining is being driven by the desire to replace traditional assembled components with a single machined structure.

Previously, for example, an aircraft bulkhead might be made up of many parts machined separately, assembled on a jig and riveted together. Now, that same bulkhead can be machined from a single piece of aluminum.

Monolithic machining slashes setup and part-handling time. "The key here is reducing operations so you're not moving things around from one machine to another," Waymouth said.

Quality also improves, because monolithic machining eliminates process variables that arise with repeated handling of a part.

Though many machines designed to handle aerospace parts are large, it's not just big companies that buy them.

Chip Storie, vice president of aerospace sales at Cincinnati Lamb, Hebron, Ky., said: "We are seeing smaller shops buying large machines. We've got a machine on our floor right now, a high-speed gantry with a linear motor, going to a shop with 75 people. It's a big machine—80' long with a 4,000-ipm feed that we call HyperMach. The shop purchased it to support production for the C-17 transport."

The HyperMach mill has the flexibility to machine a wide variety of parts, including monolithic structures. Models are available with an X-axis travel from 18' to 300', in 10' increments, and a Y-axis travel up to 128".

Addressing the fact that this type of machine can cost $1 million to $2 million, Storie said, "As the prime [contractors] are starting to move manufacturing into their tiers, those are the kind of investments that are going to be made."

Moving Costs

Much of the cost associated with high-variety, low-volume manufacturing is extraneous to the actual machining processes. A large percentage of the expense results from the movement of tooling, such as cutting tools, toolholders and workholders. Moving tooling, however, adds no value.

Ellison's Goes said, "You're only doing it because you have to. Your customer doesn't want to pay you for moving tooling." The problem can be over-

Makino

The MAG4 from Makino was designed for machining monolithic structures. It features X- and Y-axis travels of 157.5" and 78.7", respectively, comes with a 30,000-rpm spindle and permits feed rates as high as 1,575 ipm.

come, he said, by adopting technology that permits storage of a large number of cutting tools in the machine and speeds workholder changeovers.

An example of that technology is multiaxis, integrated turning centers, also known as mill/turn machines. They represent the "convergence of the machining center and a turning center into one machine tool," said Goes.

Mill/turn machines permit storage of 120 or more tools. "You can put a large amount of tooling in the machine and leave it there," said Goes. "If you equip the machine with a quick-change chuck, the workholding can be changed out in just a few seconds." The result is a turning cell that enables the user to quickly change from one part to another with minimal effort.

The mill/turn concept differs from a traditional turreted lathe, which is designed to reduce cycle time. "The specifications of turreted machines are expressed in short indexing times and rapid-traverse rates," said Goes. "The focus is on cycle time. But if all you have to make is two or three parts, what good does that do?"

Pacific Tool makes precision tooling and components for the aerospace sector and other industries. To enable it to efficiently produce a wide variety of products in small lot sizes, the company acquired a Mori Seiki MT2000 integrated turning center with a 120-tool magazine. "The larger the number of tools that you have in your storage capacity, the more likely it is you're going to have a tool already there when you need it," said Pacific's Garbarino. "This equipment has helped us to reduce lead times for low-volume repeat products because we don't have to put them through as many setups."

One such product previously required 16 different setups and operations. The new equipment has reduced that number to three, and the time required to manufacture it has dropped from a day to 90 minutes.

The machine's ability to both mill and turn means it is not limited to round parts. Garbarino described a square-sided part that began as a round bar. "You can't buy square bars in all sizes," he said, "so you've got to buy flat bar, saw it up and go through a bunch of different operations. But with our mill/turn capability, we start with a round bar, mill it into a square bar and work with it from there."

To speed workholding changeovers, Pacific Tool employs duplicate sets of quick-change chuck jaws fitted with collet pads to match the diameters of various workpieces. "The point of the quick-change jaws is that the whole jaw comes out with one quick rotation of a wrench,"

CNC 'strategist' tackles shop-floor tooling issues

To remain viable as an aerospace-parts producer, General Tool Co. seeks to continually improve the efficiency of its cutting operations. The Cincinnati shop also allocates its personnel to achieve maximum efficiency.

For example, GTC found that its CNC programmers were spending too much time away from their workstations, resolving tooling selection questions and technical issues on the shop floor. This interfered with their ability to efficiently write part programs. In response, the company established the position of "CNC strategist" to resolve tooling and process issues.

The creation of this liaison between manufacturing engineers, programmers and shop-floor personnel enables programmers to fully concentrate on programming, thereby streamlining the overall manufacturing process.

"While this level of specialization is not unique, it is unusual to see in a job shop," said GTC's supervisor of tooling and programming, Earl Wilkerson.

Another area that was bogging down was the development of workholding systems. Holding setup times to a minimum is critical if you want to be successful in this environment. General Tool attempts to use standard workholding components wherever possible, but the specialized nature of some parts requires a custom fixture.

"We never get away from it totally," Wilkerson said. "We've done some modular fixturing, which works well for a small- to medium-size machining center, but it can become cost-prohibitive when you get to the larger machines."

Prior to the addition of the strategist position, it was occasionally necessary to rush the building of a workholder, "because we didn't know we needed it until we got out to the machine shop," Wilkerson said. Now, the strategist looks "at things as soon as they come in the door—sometimes even in the quoting phase—so we get a jump on that fixturing right away."

—B. Kennedy

The following companies contributed to this report:

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Garbarino explained. "Changing the pads on the machine typically takes 1 to 3 minutes, and the pads are clumsy."

The shop acquired duplicate jaws, allowing pads to be changed off the machine. "We've got another set of jaws already loaded with the pads for the next bar diameter," said Garbarino. "When we change products, we use the wrench and we're up and running again in 30 seconds. Using duplicate sets of jaws is much more efficient."

Staying Up with Technology

A manufacturer can achieve maximum benefit when it pairs advanced hardware with innovative practices. One company that understands that concept is aerospace supplier General Tool Co., Cincinnati.

The company's supervisor of tooling and programming, Earl Wilkerson, said GTC has developed a number of manufacturing strategies that augment its ability to produce high-variety, low-volume parts. One involved creating a standard set of processing parameters and tooling selections, which the company calls the "GTC Machining Standards Document."

"We have always tried to stay up-to-date on machining techniques and to find new and innovative ways to do things," Wilkerson said. "What's changed, in light of the low-volume, high-variety mix, is what we do with the information."

Historically, process information stayed with each part. "Now, we'll experiment, and when we find something that works well, we add it to our standards document," said Wilkerson. "Later, when we have a similar application, we'll apply that standard with a high level of confidence. We don't have to spend time experimenting on every part. We just keep building on the standards—it is a living document."

The standards feature increasingly aggressive machining parameters, which are necessary to save time during certain machining applications. An example is machining prototypes from heavy forged rings, which is common at GTC. "Feeds and speeds must be fairly aggressive," said Wilkerson. "They have to be or you'd be cutting forever."

GTC understands that continually minimizing time in the cut is necessary to succeed in a tough business. But the company doesn't try to achieve that ongoing goal through high-speed machining, the definition of which varies from shop to shop, according to Wilkerson. "We're more interested in high-efficiency cutting than high speed. We run at 10,000 to 12,000 rpm. Most people would not consider that 'high speed.' But when we're cutting titanium at 100 ipm and getting good material-removal rates, we know that we can be competitive in the aerospace industry."

Any aerospace shop seeking to maximize its competitiveness must correctly deploy manufacturing technology. Ellison's Goes said that "technology is meaningless unless you have an operational process to deploy it." Shops must find "better ways to do it. If you don't continuously evolve your company, and if you don't employ new technologies and new operating processes, you are going to go away. It's as simple as that."