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High-Flying Parts

New machining concepts can help aircraft manufacturers overcome the challenges of cutting high-strength, heat-resistant materials.

There are about 17,000 passenger and freight aircraft currently in operation around the world, but the skies are set to get a lot more crowded. Experts predict that 25,000 new aircraft will be required by 2025. Although booming, the aerospace industry faces rising raw material prices, increasing use of difficult-to-machine materials and limited production capacity. New machining strategies will be needed to provide quick, process-reliable solutions.

Titanium, Inconel and other high-strength, heat-resistant alloys are joining carbon fiber-reinforced polymer composites as the primary materials used in aerospace engineering, typically replacing aluminum. Aerospace parts manufacturers often need to machine a combination of materials in a single workpiece because a metal, such as titanium, might be sandwiched between layers of composite material to stabilize the composite structure.

Lightweight construction is becoming the norm as airlines seek to significantly reduce fuel consumption. For example, Lufthansa wants to achieve a 1.25-gal. aircraft (1.25 gal. of fuel consumed per passenger per 100 miles).

Achieving this goal, however, will be an expensive proposition for parts manufacturers because machining lightweight materials will require significant investment in new machine tools and tooling solutions. This might involve switching from large gantry-style machines with up to 6 or more spindles in a row to machining parts in a single setup using machining centers to gain flexibility. But these costs can be offset by using ingenious new machining concepts.

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In today's aircraft manufacturing industry, long tool life and maximum process reliability are critical. In addition to working with challenging raw materials, the industry needs to achieve machining rates of up to 90 percent. In other words, a machine has to create chips 90 percent of the time.

Rationalization Potential

A range of aerospace components continue to be produced from solid blocks—and for good reason. These components are exposed not only to extreme environmental influences, but also to unusually high mechanical stress. The components must be largely tension free to preclude the possibility of fracturing and other damage, and this is enabled by machining them from a solid block, but hundreds of hours of work can go into a finished component.

So is there a way to improve productivity? Given the cutting speeds and tool loads involved, parts manufacturers have to work within certain limits. They are not expecting quantum-leap developments with most difficult-to-machine materials. Cutting speeds from 150 to 200 sfm for titanium, for instance, are already considered high-speed cutting. The only way for users to open up new potential is by changing machining strategies.

Until a few years ago, aerospace engineering was dominated by HSS tools, which need to be applied at slower cutting speeds than carbide tools. But as the use of traditional tool materials recedes, solid-carbide and indexable-insert tools are making inroads into aircraft production by offering increased productivity. This has required investment in new machines or cost-intensive conversion of existing machines to provide the rigidity needed for running more brittle carbide tools and machining at the higher parameters suitable for carbide. This poses an enormous problem to manufacturers, who are finding that their return on investment is taking too long.

Simply changing to higher-grade tools may not be enough to overcome this particular problem. Consequently, toolmakers are taking a holistic view of the manufacturing process by working with the machine tool builder and end user from the beginning of the product development stage.

Affordable Safety

Unlike the automotive engineering industry, where toolmakers have been involved in early product development stages, toolmakers' aerospace industry experts are often called in after development has occurred. This is due largely to the industry's established tradition.

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Over a period of decades, airlines were seldom concerned with costs, as safety was paramount at any price. This era ended with the onset of globalization and the upsurge in cheap air travel. The aerospace industry is gradually realizing that although safety is the most important factor, it has to be affordable. This is placing aircraft manufacturers and their suppliers under enormous pricing pressure, and they are eager to learn lessons from other industries, primarily the automotive industry, in which the biggest challenge is competing with low-cost Asian manufacturers.

For example, automotive OEMs share the risk during development projects with their Tier 1 and 2 suppliers, spreading manufacturing operations to various suppliers on a large scale. Suppliers then delivery components ready for final assembly.

End users should provide toolmakers with the requisite data during the product planning phase, allowing a toolmaker's research team to determine the optimal cutting edge geometry and match it with a coating using a standardized series of tests. The efforts are focused on increasing tool life.

Aircraft manufacturing involves a significant amount of pocket milling because of the large number of structural components involved, such as metal forgings or plates that feature numerous cavities.

This makes it essential to find the right strategies to effectively machine pockets, including strategies for chip control and evacuation. When applying a high-performance cutter for pocketing, a rule of thumb to generate appropriate-sized chips with a thickness from 0.006" to 0.008" is to run at a 0.060" to 0.080" DOC and a 0.015" to 0.020" fpt.

Finding the right strategy not only involves the workpiece material, but the machine, tools and fixture as well. For instance, one approach is to drill starting holes into pocket corners and then apply a shoulder mill to remove material layer by layer via 2-axis milling. Depending on a machine's torque and horsepower, an appropriate DOC for each layer is from 0.150" to 0.200".

Alternatively, end users can remove stock in pyramid form with a small WOC at full DOC where the tool's radial engagement and axial engagement is changed with every pass. This is often done when a workpiece material, such as stainless steel, creates notching on an insert or tool. Because the DOC notching is axial and on different positions along the cutting edge, this technique divides the DOC notching and spreads it along the cutting edge.

And where long tool projections are involved, plunge milling is generally the right strategy.

Coating Considerations

Despite precisely adapted cutting edge geometries, there is still a technical restriction on cutting speed when machining aerospace-grade materials. The only way to achieve significant productivity improvements is by applying tools with a large number of teeth and extending tool life. This depends on choosing the right tool coating. The optimized coating not only reduces wear, it also protects the cutting edge from the effects of heat.

For example, PVD aluminum oxide is particularly effective for machining aerospace-grade materials. Its main benefit is the ability to withstand significantly high levels of heat with little tendency to form built-up edge and microfractures at the cutting edge. When cutting titanium, heat generation at the cutting edge poses a problem because of the material's poor heat-conduction properties, causing most of the heat to be diverted into the cutting edge. However, when a coating with greater resistance to heat is applied to the cutting edge, heat is forced to flow in another direction, i.e. into the chip. The heat shield provided by PVD alumina increases service life by up to 50 percent when machining titanium, and, in many cases, allows a part feature, such as a pocket, to be completely

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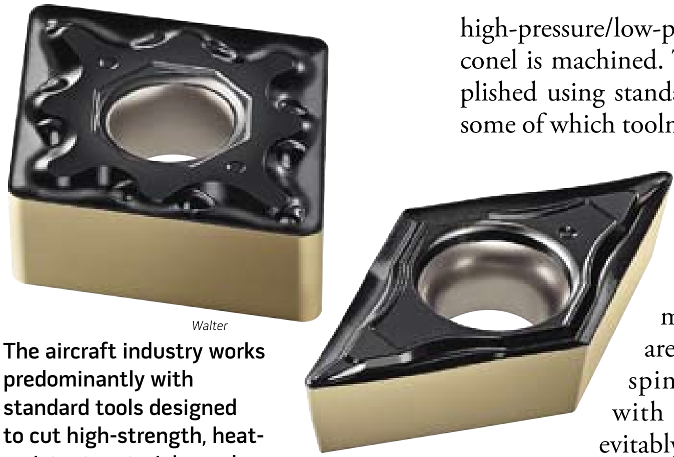
machined without a tool change. This reduces machine downtime.

Another example is improved Al_2O_3 coatings. It's typical for an Al_2O_3 coating to have a rough surface finish when deposited on a tool, so Walter puts a coating of titanium carbonitride on top of its Al_2O_3 coating and then removes that top layer from the rake face by shot peening. This provides a smoother surface and reduces friction when chips hit the cutting edge, which extends tool life. It also creates a distinctive-looking two-color insert, which enables easy recognition of flank wear.

Machining Methods

Applying high-performance cutting tools specially tuned to the requirements of the available machine is one approach to advancing productivity when making aerospace parts; the use of new machining methods is another. Using modern machining centers, cycle times can be dramatically reduced.

For example, changing production methods for landing gear components, which are up to 10' high and



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The aircraft industry works predominantly with standard tools designed to cut high-strength, heat-resistant materials, such as titanium 10-2-3. By using different Tiger-tec cutting materials, Walter significantly increases tool life. And with the "PVD-Tiger" aluminum-oxide coating, the company's material development team combined the positive attributes of CVD and PVD coatings.

made of titanium 10-2-3 or titanium 5553 depending on the model, can reduce cycle time.

In the past, helical cutters were guided backwards and forwards in 3-axis machines, allowing the workpiece to be cut to the required dimension. But with newer 5-axis turn/mill centers, the component itself rotates, which can accommodate turning, profiling and shoulder milling tools. Places inaccessible to turning operations are machined by turn milling. The alternative is the constant traverse of a profile tool on the Z-feed level, which removes material a step at a time. What have been considered traditional methods in the tooling and moldmaking industries are now finding a place in the aerospace industry.

Another example of how machining methods have changed is engine construction. There are four main areas in an aircraft: the fuselage, power plants (engines, power generators), undercarriage and flight controls. Each of these areas requires different materials and machining methods. Engines call for machining titanium and Inconel, materials capable of withstanding high dynamic and thermal loads. To produce an engine's rear components, such as the high-pressure/low-pressure turbine, Inconel is machined. This can be accomplished using standard high-feed tools, some of which toolmakers have adapted for machines with low output.

Considering the enormous boom in aircraft manufacturing, there are simply not enough spindles to keep pace with demand. This inevitably leads to long lead times. This situation has to change radically, as competitors from Russia and China are placing established producers under pressure, not only in terms of pricing but also in terms of innovation. Aerospace parts that are not difficult to premachine, such as engine casings, are already being produced in those countries, and sooner or later manufacturers there will obtain the equipment and know-how to produce complete sophisticated components.

The ability to combine high quality with enhanced productivity is the challenge faced by the aerospace engineering industry today. Meeting this challenge, which will produce totally new machining strategies in coming years, may even provide a model for other industries. **CTE**

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