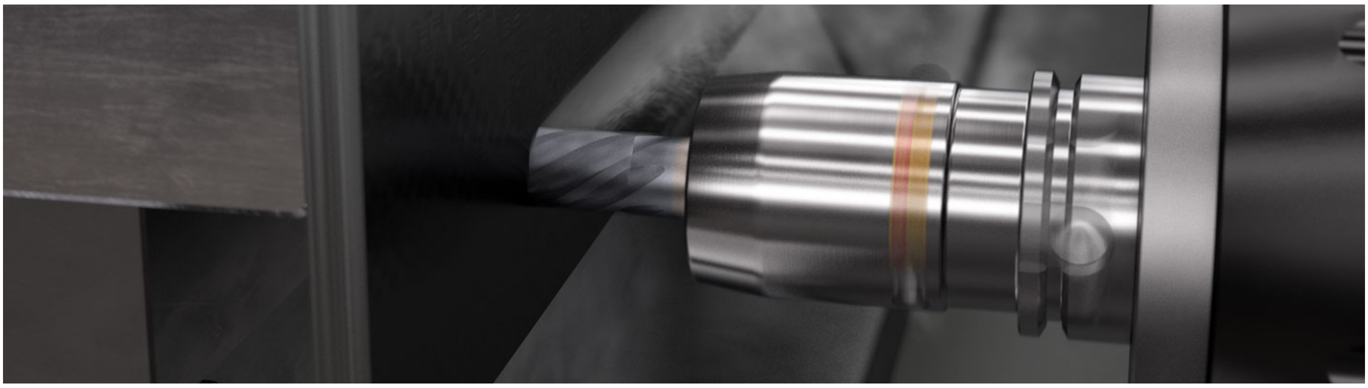

Machining

Aerospace In Focus: Drilling and Milling CFRP Composites

Holly Martin | Jul 17, 2018

In aerospace, working with lightweight composite materials is the norm. We recently spoke with Sandvik Coromant to discuss common metalworking problems in carbon-fiber composites and the ways to overcome them.

Composite materials such as carbon fiber reinforced polymer are incredibly abrasive and require different approaches to milling and drilling to avoid delamination of the layers and pulled fibers. Standard tools and methods designed for working metal just won't cut it when it comes to manufacturing aerospace components made of these materials.

"Carbon fiber gives you superior strength with much less weight, so in commercial aerospace, that allows for some really positive things," says David Den Boer, aerospace industry specialist and engineer at ***Sandvik Coromant***. "As the plane gets lighter, the engines become more efficient."

For example, the Boeing 787 is made of about 50 percent CFRP and uses 20 to 25 percent less jet fuel than a comparable aluminum plane. The composite fuselage is manufactured in complete round barrel sections, rather than in segments and pieces. However, constructing such a plane leads to challenges in the machining development process.

"Normally if we're working on an engine part, we would experiment with the cutting tool and the process on the component itself, but we can't practice drilling holes in the side of a $30 million fuselage," says Jeffrey Washburn, product manager at Sandvik Coromant. "So all the process testing and development takes place separately on 'coupons' that closely represent the final component."

Want to go deeper? Learn more about the lightweight yet strong materials being used in aerospace. Read: "Cutting Challenges: Mixed-Matrix Composites and Fiber-Reinforced Composites."

Tools for Milling and Drilling Composites

"Carbon-fiber material is very abrasive," says Den Boer. "So with a typical carbide cutting tool that may last for several hundred holes on a metal such as aluminum, you might only get 20 holes on CFRP."

To last longer, machine tools for CFRP must be either veined ***polycrystalline diamond*** (PCD) or coated with a layer of submicron diamond particles—which makes each tool more costly than traditional tools. But according to Washburn, the right way to measure the cost of producing a part comes down to the cost per hole drilled, not the cost per tool.

CFRP Debonding and Delamination Explained

Carbon fiber reinforced polymer (CFRP) is a composite material consisting of two parts—a matrix of liquid polymer, such as epoxy, binding together layers of carbon fibers. The fibers are woven into flat sheets or tapes, which are then laid into or applied onto the surface of a mold. The polymer can be pre-impregnated within the fibers or brushed on between layers.

“After putting down the layers, you wrap a bag around the component—even an entire Boeing 787 fuselage—and put it in an autoclave, which heats it up and applies vacuum pressure to the bag,” says David Den Boer, aerospace industry specialist at Sandvik Coromant.

The heat and pressure bond the layers together and remove any air bubbles that could contribute to layer separation in the form of debonding or delamination.

“A debond typically occurs on the interior of a piece when the amount of polymer between layers is low,” says Den Boer.

In contrast, delamination results from machining a composite part without the proper tooling.

“As you mill or drill a part and break out a hole, it can cause delamination, or separation of a layer on the outer surface,” says Den Boer. “So debonding and delamination are very similar, in that they both result in layer separations, but they have different causes."

Another consideration is the cost of tool changes.

“Let’s say you’re milling the top of the fuselage on a big gantry CNC machine that takes 10 to 15 minutes to come down, change out a new tool and go back up to the top,” says Den Boer. “Comparing the machine time needed for one diamond-coated tool on an entire 787 section with changing out 80 or 90 carbide tools, the economics can be justified.”

Tooling material is not the only difference for CFRP machining. Unlike metals, the two most challenging problems in milling and drilling CFRP are fibers in the hole and delamination, according to Washburn.

“When they analyze the quality of a hole, it may be perfectly to size, but if the cutting action of the tool leaves uncut fibers in the hole itself, that’s not considered a good cut,” Washburn says. “And if you’re milling along the edge of the surface, you want to keep the tool sharp enough to continue to cut the fibers cleanly, without pulling them out of the surface or delaminating.”

> **“Let’s say you’re milling the top of the fuselage on a big gantry CNC machine that takes 10 to 15 minutes to come down, change out a new tool and go back up to the top. Comparing the machine time needed for one diamond-coated tool on an entire 787 section with changing out 80 or 90 carbide tools, the economics can be justified.”**
> David Den Boer
> Aerospace Specialist and Engineer, Sandvik Coromant

According to Washburn, tools designed for CFRP have a very different set of geometries, depending on the process and the application.

“A typical ***end mill with a helix*** always wants to lift the material from the cut, and so if we try to apply a metal cutting geometry to carbon fiber, that will tend to delaminate the material, because the helix angle is pulling up on the surface,” he says. “The answer is to design tools that pull up from the bottom and push down from the top at the same time—to kind of squeeze the material together so it won’t delaminate.”

Stacking CFRP with Metals

But these special tools typically won’t work in metal applications, which leads to another complication.

“Composites are often stacked with other materials, so you may be drilling through CFRP, for example, and then hit a layer of titanium or aluminum—and the tool must be able to machine both to produce a single hole,” Washburn says.

The differences in toughness and abrasion between the materials in a stack call for creative solutions.

“One challenge to machining CFRP stacked with metal sheets is that a lot of these airplane components can’t be exposed to cutting fluid for cooling and carrying away chips,” Washburn says. “This presents a problem, for example, when trying to machine titanium with no coolant.”

“People try different things to accommodate the different layers, such as adding a chip breaker for an aluminum sheet, to prevent long chip strings from tearing up the fibers and making the hole too large,” says Den Boer.

“If the holes will be drilled with automatic drilling units, some of the newer ones have programmable RPM and feed rates, so you can drill the CFRP in a stack at one speed and feed and as soon as you hit the titanium, you can change the cutting data, and optimize it for each layer,” Den Boer says.

Have you ever run into problems cutting CFRP composites? Tell us what happened and how you resolved it.