Drilling Composites: The Development of Dedicated Solutions to Optimize Performance and Results

By: Christer Richt, Sandvik Coromant

The growing use of composites and composites stacked with metals is having consequences for machining, demanding a new approach to how to effectively cut materials. Even though the amount of machining needed on composite components is typically less than on metal ones, the properties of the materials can make them more demanding to machine to critical specifications. The need for material-dedicated solutions for composites is high, in many ways mirroring the demand that arose when the use of titanium became widespread. Today, diamonds are a composite machinist's best friend.

Composite machining involves fracturing, or shattering, the fiber part of the material. With these types of materials, obtaining clean cuts requires a new approach in terms of tools and processes. Due to poor heat conduction and no chips being formed, the amount of heat generated during machining becomes a significant issue, posing risk to the resin within composites. As such, composites illuminate weaknesses in the machining process that may be overlooked or irrelevant when working with metals. Their broad variation, general unpredictability and growing importance in a wide range of applications demand an approach of continuous improvement to maintain a competitive machining process.

Hole generation has emerged as the most common machining process when working with composites. Preparing the application of fasteners in composite-based framework and components represents a substantial aspect of machining within the aerospace industry. Even with unified structures reducing the amount of assembly, making holes remains a dominant driver of efficiency, cost and safety issues. As such, it receives considerable efforts towards improving performance, consistency of quality and security.

Satisfactory drilling of holes in composite and related stacked-material components presents a significant challenge. Success requires defining and addressing a number of factors that determine the most suitable cutting tool and process. Key attention should be paid to the properties of the specific material involved, hole specifications and quality requirements, equipment being used, set-up stability and the volume of holes to be created.

Many types of composites exist in the family of carbon fiber reinforced plastics (CFRP) that dominate aerospace applications. The addition of titanium and aluminum combinations in stacked materials further complicates the challenge. Achieving sufficiently round and clean holes is of the utmost importance, as they are typically found in fastener joints that affect fatigue values for structures. Correct selection and application of a cutting tool provides the key to achieving holes of the necessary quality and minimizing dust contamination during the machining process.
Quality indicators traditionally applied when drilling metal often fail to apply with composites, due in part to a lack of chips and the fact that conventional surface finish may not be an indicator. Instead, manufacturers typically measure composite hole quality in terms of degrees of any separation of the bottom layer in the material (delamination) and the occurrence of residual fibers in the hole from fraying (splintering). The inability to directly detect these phenomena presents another challenge, along with getting the cutting action of the tool right. Moreover, hole quality often deteriorates below acceptable levels before indications of poor tool performance appear.

As with most cutting tools, success in drilling composites depends heavily on achieving the best combination of cutting edge geometry and tool material. The hardness of fibers found in composites results in a very abrasive material when machined. Bonded in the weaker resins, there are tendencies towards fibers being pulled out, instances of elastic mismatch and occurrences of interlayer fractures. This makes hole walls and entry and exit points prone to damage that puts them outside of quality limits. Additionally, when dealing with stacked materials, the tool must provide a high and broad capability of penetration.

In establishing the properties of a specific material, testing remains a vital complement to supplier recommendations when determining the best tool and cutting data. Although tool life has traditionally been the main consideration, manufacturers must increasingly consider speed and efficiency to remain competitive. Even for those with prior experience in composite machining, the appearance of a new material in the shop requires a fresh approach. These are not homogenous materials and they present a range of machinability exceeding that of metals. A new material needs to be identified according to surface, structure, fibers, resin and thickness. With stacked materials, the type and thickness of metal used must also be taken into account.

Critical factors in tool selection include maintaining dimensional and finishing control, determining the appropriate level of pre-drilling, selecting one or two drill passes and evaluating if reaming is necessary. Additionally, expensive components significantly increase the cost of any mistakes, so secure processes and high reliability play a vital role in minimizing costs and maximizing productivity.

The capability and stability of the equipment, machine and set-up being used influences the choice of tool. Hole making equipment may be automated, power-fed or handheld and take the form of a CNC machine, robot, portable power-fed machine or operator’s hand tool. Cutting tools are usually dedicated to one or more of these means. Additionally, it may be necessary to compensate for variance within the demands of the operation or experience level of the operators, which can be achieved with tool selection.

Hole volume also drives the decision-making process through its impact on total cost. Maximizing efficiency in a large volume of identical holes in one type of
composite material requires an optimized, higher-priced tool. Manufacturers dealing with lower volumes of holes across a variety of composites, components and set-ups benefit from other alternatives.

**Modern Solutions**

Keeping all of the previously mentioned variables in mind, manufacturers face a wide selection of cemented carbide tools that are diamond coated or diamond veined and come in the form of standard, semi-standard and engineered solutions. Each aims to provide state-of-the-art performance and results in a specific segment of the large range of composite and stacked materials currently being used in aerospace and other applications.

Polycrystalline diamond (PCD) is a very hard tool material, ideal for machining both composites and stacked materials. Cemented carbide drills with cutting edges of PCD apply to a significant portion of composite hole-making applications. In many situations, it provides the best option for achieving higher quality levels and consistency while also boosting productivity.

Carbide offers the means to strengthen the tool through the cutting geometry and the shank of the tool, optimizing cutting action and maximizing clearance and material evacuation. This makes carbide-based drills especially suitable for many unstable operations that involve hand tools, where uneven thrust from operators and variations in guide-bush/drill clearance are issues. The same properties position these tools as ideal solutions for many power-fed, single pass operations in stacked materials. The benefits of these tools arise from the complementary nature of carbide and PCD. Carbide is strong, but wears quickly. PCD is very wear resistant, but more brittle. Combined, they provide an excellent hole-making solution in many applications.

**Diamond-Coated Drills**

The market now contains a substantial range of standard, tailor-made and engineered drills with a PCD coating. Available in a broad variety of grades and geometries, these types of tools satisfy needs across diverse material and machining conditions. PCD-coated drills offer optimal hole-making in composites varying from fiber-rich to resin-rich, as well as provide general alternatives suitable for stacked materials, including titanium.

PCD-coated drills optimized for fiber-rich materials can offer the added benefit of minimizing the tendency for fraying in holes. Some of these drills contain spurs at the periphery to better cut fibers, thus avoiding splintering. These drills are also suitable for stacked-material combinations involving composites and aluminum.

At the other end of the spectrum are PCD-coated drills developed to specialize in resin-rich composites. Some of these feature double-angled geometries to achieve softer entries and exits, minimizing the risk of delamination. These drills are also often applicable to drilling in glass-layered composites.
In addition to the range of available cutting geometry alternatives, these tools feature a range of PCD grades to maximize tool strength and provide long tool life, close tolerances and shorter machining times.

**PCD-Vein Technology**

Based on a process developed and patented in the 1980’s, PCD-vein technology offers an advanced, high tech method for integrating PCD in carbide. This innovation allows optimal use of the hard, wear-resistant cutting edge in a tough drill shank. The carbide drill is equipped with a PCD edge brazed into a slot strategically placed away from the drill tip, thus allowing the use of a high-strength braze joint. By grinding the final tool geometry, the edge becomes shielded by the carbide portion of the drill to some extent.

The PCD-vein process enables the production cutting geometries that were previously impractical or impossible to achieve with conventional PCD-bit processes. It also allows variations in tool design to provide precision holes in applications ranging from those with less rigid set-ups to very stable, high volume operations.

Most typically, PCD-vein drills are engineered to optimize performance and hole-quality consistency in automated operations. The technology provides a sharp geometry that retains its cutting edge in even the most abrasive of composites. It also enables a unique design where the tool corner can be strengthened to allow higher cutting speeds in combination with tight entry and exit limits.

Drills using PCD-vein technology can also be engineered specifically for stacked materials containing metals and composites. Such examples can feature micro-grinds located in concentrated areas of high stress, providing the drill with the ability to remain sharp and precise throughout a long tool life. The cutting edge cuts composite fibers with a low thrust force, resulting in minimal fiber breakout, delamination and exit burrs on the metal in the stack.

**The Solutions of Today and Tomorrow**

Conclusively, dedicated cutting tools are critical to achieving success in hole-making in components made of composite and stacked materials. Recent innovations have provided higher consistency over longer tool lives with greater security, both in terms of operators and eliminating scrap parts. As demands continue to increase in these areas, as well as in regards to shorter throughput times, cutting tool providers must continue to build on their experience and expertise through extensive R&D efforts. Advances in tooling solutions will play a vital role as the use of composites becomes widespread in a greater variety of industries and applications.

*About Sandvik Coromant and Precorp*

As established innovators and suppliers within cutting tools and solutions for composites machining, Sandvik Coromant and Precorp joined forces to develop
state-of-the-art, co-branded products. The companies have established a wide range of standard and engineered carbide-PCD tools to address the vast array of characteristics of composite materials, combinations of stacked materials and varied set-ups that prevail in manufacturing.