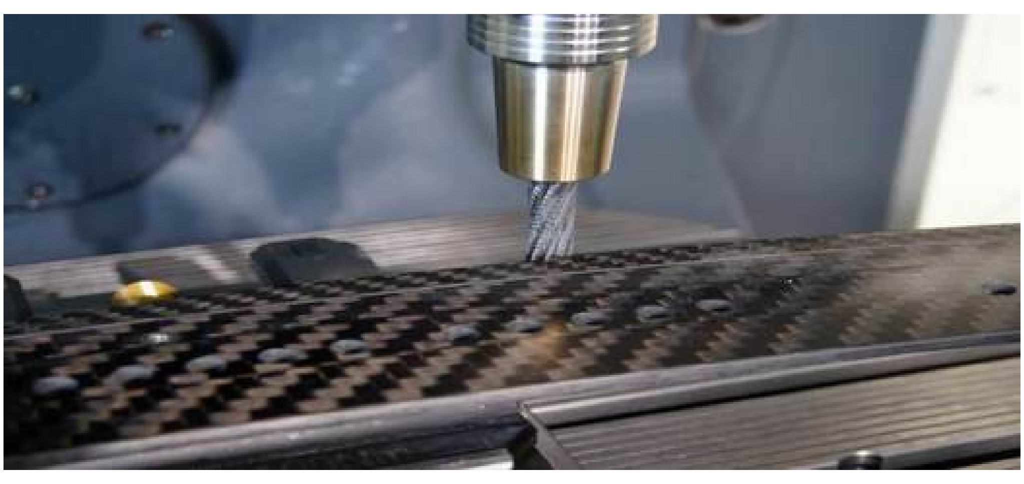
Cutting Edge

SGS The Cutting Edge

Solid Carbide Tools

Composite cutting tools: Here we look at the questions that industry needs to ask when cutting composite materials – answers provided by Dave Cawkwell, UK Sales Manager, SGS Tool Europe Ltd



Why are specialised composite cutting tools needed for composites as opposed to using traditional metal cutting tools? What kinds of tool design geometries are available to help?

Traditional cutting tools will work for a very short time, until they become blunt. The tool will therefore start to push the material rather than cut it and it will cause delamination.

It is down to the multi-directional, multi-characteristic nature of the material, you are not working with a crystalline structure as you would be in metal you are working with a resin and a fabric. The geometries on standard cutting tools are designed to cut crystalline structure materials while with composite you have multiple layers. Traditional cutting tools with their helix angles will either push or pull the workpiece material in a certain direction. So, a standard right-hand helix tool will always try to pull the top layers of any composite.

Specialised composite tools are needed because of their very specific geometry adapted to the material group. They are generally much sharper and feature a slower helix angle, making the rake angle critical to the success of the tools performance. Edge strength is exponentially greater with a slower helix, and heat build-up is better controlled.

Performance gains in solid carbide are achieved through multiple teeth; the larger the number of teeth/flutes is the better the tool life will be as the cutting action is shared by a great number of cutting edges. Cutting tool edge wear is by attrition caused by a number of factors such as vibration, poor rigidity as well as the abrasive nature of the workpiece material. In use there is microscopic breakdown of the carbide grain structure. Sharing the wear across an increased number of teeth will thus slow the process.

Specific carbide grades help along with coating designed to support the shear action and allows SGS to slow the wear process even further. The consistency of the carbide grade is vital for such tools as well as the exact chemistry of the substrate which needs to be controlled precisely as it has an enormous influence on the coating, especially if it is a diamond coating.

What are the particular challenges when it comes to machining composite materials. What has to be taken into account in terms of feed/speed, swarf removal, heat build-up, delamination, cracking, fibre breakout?

By far the largest application for composites is drilling, followed by trimming and finally slotting and pocketing operations.

If you just need to generate a hole a jobbing drill will achieve that, but the tool life will be very poor. However, if you need a precise hole you need drills and cutting tools designed for the material and the process. Usually if a customer has a series of holes to generate, SGS recommend a pilot drill with a diameter below the finished size followed up with an SGS CCR tool, (Carbon Composite Router) to interpolate the various size holes required. So just two tools can create multiple diameter holes, which is more efficient if the size of the hole required is not a standard diameter and a special drill would have to be made. SGS has carried out cutting trials in-house and at various customers and test data proves that interpolating the hole to the same or better tolerance than drilling can be achieved, with a finish far superior and fibre breakout being completely eradicated.

This hole generation method is vital where there are mixed materials in a stack or when the composite has an inclusion such as a conductive metal mesh. Fibre breakout can be overcome using this method and a SGS four straight flute cutter that can cut multiple materials in a stack. If the metal is non-ferrous a CCR tool can be used.

SGS also encourages the interpolation of chamfers in composite material with bespoke chamfer tools. If you plunge a chamfer tool in, it has various surface speeds at different points along the cone diameter; by milling it you can control the chip thickness.

For trimming or free form machining, the direction of the cutting tool is very important in relation to the path of the weave of the composite material. If you machine a unidirectional weave, the direction of the cut has to be applied correctly for the orientation of the top weave.

Evacuation of the material chips can be a problem when slotting composite parts that is the reason why SGS has developed a CCR tool with a smaller diameter core and deeper flutes in order to carry the volume of chips away from the cutting interface.
Heat build-up is a problem and you need to remove swarf, but most heat build-up comes from the tool being run too quickly. The most common mistake SGS comes across in the industry is the elevated speeds that are being applied, with applications running at surface speeds of 400 to 500 m/min burning the tool out. SGS cutting data has been thoroughly researched and tested, and it is generally much slower than the rest of the market. However, the feedrate is maintained so the cycle times are not slower and the tool life is dramatically increased.

Heat build-up can also plasticise the resin, the bonding element of the composite, affecting the integrity of the material. If the resin approaches a molten state there could be some crack propagation, delamination or inclusion of swarf material. The hole size tolerance and finish could also be affected and the resin could become more brittle, no longer functioning at its maximum design strength.

What R&D has been carried out when it comes to machining different composite materials over the years? Are the different challenges posed by different materials, such as carbon/glass fibre, plastics, biofibres, metal matrix, laminates etc.?

To cut composites a neutral interface between the cutter and the material is required so it is not pulling up on the workpiece. Originally the Series 20 CCR were developed for trimming operations for components on the Boeing 787 Dreamliner in 2009. Subsequently it has been developed into a ball nose cutter for free form machining, a roughing tool, an end mill for finishing pocket floors, and a plunge tool.

While material and manufacturing process constraints will decide if a composite is machined dry or if a coolant can be applied, the R&D team at SGS is currently investigating cryogenic machining with a sub-zero aerosol to eliminate the heat build-up and allow highly elevated cutter speeds.

Material characteristics

Each material is different and each one possesses a significant number of variables. A composite generally has a fibre material of carbon, glass or aramid. This can be in a number of forms, NCF, woven, preform, unidirectional or chopped strand. It can be mixed with a core material such as copper, aluminium or titanium mesh, model board and honeycomb formed segments. Next is the choice of matrix bonding material, which includes polyesters, phenolics, polyimides, polyamides and epoxies. The extraordinary number of possible combination makes the possible variations phenomenal, before even considering the production process, such as prepreg or dry fabric plus a resin for hand layup, resin transfer moulding or automated fibre tape placement.

In application, the cutting strategy has to change at different points around the workpiece to match the weave of the composite.

What are the latest tools developed for machining composites?

The new Series 120 8-facet drill has been designed and developed to successfully create accurate holes without splintering or delamination of the composite stack. The stable, double margin construction drill is manufactured exclusively with the SGS Di NAMITE crystalline diamond coating for even wear, extended tool life and improved finishes. In operation the faceted point steps out from the centre working effectively as a series of chamfering tools, giving a more stable cut and the ability to cleanly cut the composite.

Extending the popular Series 20 CCR SGS has added the new Series 31. The new series of carbon composite routers feature fewer and deeper flutes than the original Series 20 CCR to avoid clogging during demanding applications. Both the new Series 31 and the Series 20 CCR expansion are available with or without the proven Di NAMITE coating.

For milling and finish cutting operations on carbon composite material, the new Series 25 Compression Router incorporates a left- and right-hand helix, and is designed to compress the workpiece to eliminate the fraying of material.

The Series 27 variable geometry slow helix end mill is designed for milling highly abrasive materials, where the tools benefit greatly from the optional Di NAMITE coating. The innovative cutting tool technologies combine substrate, geometry, edge preparation and coating for an optimal combination that can withstand the complex conditions faced by manufacturers machining composite materials.

All the cutting tools are standard catalogue items so there is no cost penalty for customers producing composite parts.

What are the various applications for PCD, diamond coated and carbide tools how do they compare with each other?

Because the fibres lay at different angles through the composite material the cutting tool is effectively cutting with and against the weave or 'grain' of the material all at the same time on the same cutting edge. The reality is that the cutting tool is the best compromise for all the conflicting issues contained within the composite material. This is why for some composites PCD tooling works best, while for others coated or uncoated carbide offers a better solution, with significant cost savings.

www.sgstool.com