

Cutting Tool Technology for Machining Composite Curing Tools

Peter Mueller-Hummel
Mapal Inc.

ABSTRACT

In the present study, a fully controlled experimental protocol is used to investigate the difference in milling Invar and HexTool® [1] for composites curing tools. The main difference is the use of the different strategies: conventional milling is better than climb milling, High feed / low speed better than low feed / high speed, high depth of cut better than low depth of cut, air coolant better than water coolant, diamond coating better than solid carbide, sand finishing better than chip removal, torus tools better than ball nose tools. Therefore, using metal machining strategy on composite curing tools leads to cracking and delaminations in the composite surface which causes the resin flow to infiltrate these cracks during the moulding process. Consequently, parts demoulding will destroy the surface of the curing tool and make it unusable without repair. The new technology approach will lead to a higher integrity of the composite surface and enhance the life cycle of the curing tool.

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INTRODUCTION

Major factors to be considered in the design and fabrication of tooling for structural and mechanical components are: (1) dimensional tolerance control and configuration stability, (2) location of parts in a structurally reliable assembly to give the lowest possible cost, (3) contour and size of the part, and (4) control of fiber orientation. Other significant factors which control final tool concept selection are cost, tool service life, heat up rate, total energy requirements, production rates and related facility costs.

The tooling required to fabricate most composite parts can be subdivided into several major categories: composites tools and metal tools. Again, for these two categories, the most used metal for tools is Invar and the new developed tool material for composites is HexTool®.

HexTOOL® is Hexcel's new patented composite tooling material that enables the tolerance accuracy achieved with metals to be combined with the extreme lightness of carbon fiber composites. This new concept for lightweight, efficient large-scale tools is cost-effective compared with conventional composite tools and metal molds, especially those made from Invar®. The nice thing on using this material is that the machining is much easier and the steps for machining can tremendously reduced. The problem is that the machining of composite is quite different from the machining of metal. Mostly the composite tools are machined using the same

machine and using the same cutting tools and strategy. This leads to different type of surface defects on the composite part. After the first curing and demoulding, the defect of surface get larger and with that the life of the curing tool gets knock down tremendously.

ROUGH MILLING OF CFRP

Composite panels were manufactured using HexTOOL® M61/2000 - BMI from Hexcel and used to test the cutting conditions. The results of that test verified the theoretical approach to describe physical differences between metal and composite machining illustrated in [figure 1](#).

Out of that investigation we got some very interesting results and that leads to a fundamental comparison between machining of metal and machining of composites. While metal is homogeneous, has a high heat resistance and has in general an isotropic behaviour, composite is generally considered anisotropic and therefore heterogeneous.

In general, metal shows an elastic/plastic physical behaviour under fatigue while composite remains elastic until break. This is related to the rules of continuum mechanics for metal compare to fracture mechanics for composite. Therefore, machining of metal involves a heat up in the primary shear zone around its melting point, which is not the case for composite where heat is generated by friction.

Composite granulates have to be removed in a different way than a continuous long metal chip.

Process Know-how in machining CFRP		
	Metal	Composite
material	homogenic, high melting point	Fibre structure, low melting point*
structure	reversible (post treatment)	irreversible (Pyrolysis)
failure analysis	elastic / plastic	elastic, no thermal micro spring back
phys. description	continuum mechanics	fracture mechanics
process model	knife cuts the butter	Spoon impacts and break the shell of an egg
process heat	temperature equal to melting point	cold process (heat due to friction only)
shape of waste	coherent chip → chip flute	powder or granulate → worm conveyor
MMS / KSS	Allowed / Allowed	Allowed / Allowed (til 5% oil)
milling strategy	climb milling	conventional milling
pre- and post-treatment	roughing + finishing	roughing only

*Thermoplastic Matrix

Figure 1. Comparison of machining Metal versus Composite

Another important aspect to take in account is related to metal structure recovery, which can be done using mechanical, heat or physical post treatment. In that case and especially for thermoset based composites, no structure can be recovered due to irreversible curing reaction inducing very high level Van Der Waal forces between the resin molecules leading then, to integrity loose. For these reasons the strategy of conventional milling is well suited for machining CFRP than the climb milling which has been commonly used in metal machining.

THE RIGHT STRATEGY FOR CFRP MACHINING

Figure 2 shows as comparison of two different strategies machining composite. The most important thing is the orientation of the cracks, the dust removal capability and the temperature on the freshly machined surface. Figure 2 shows also the capability using conventional and climb machining for machining.

The crack, generated in climb machining is perpendicularly oriented to the surface. During conventional machining the fracture runs in the direction of the feed, thus, supporting the cutting of the material. Even for very thin or instable clamed curing tools, it's very important that the direction of the cracks have to be oriented into the direction of the feed. The orientation of the cracks in feed directions also lowers the noise and the vibrations during machining process, because the polar moment in feed direction is much higher than perpendicular to the surface. In other words the material is more stable in the horizontal direction of the feed than in its vertical axis.

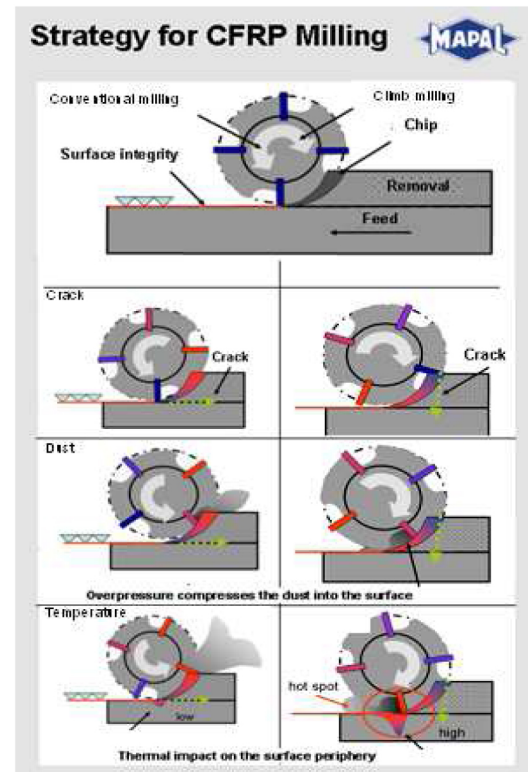


Figure 2. Cutting Forces in direction for conventional milling

This theory was confirmed by various test series for verifying the models by rough machining of M61/2000- BMI material for the curing tools. Furthermore, the following features leads to a better results in machining of CFRP:

- Cutting tools must have appropriate space volume in the flutes to avoid overload at high feed rates.
- Overload leads to an increase of friction, overheating and due to that, an early failure of the milling cutter.
- Further possibility to increase the feed and to reduce the noise is to use more cutting teeth on the tool. Therefore the machine has to be rigid and stiff enough as shown in figure 3.

Apart from appropriate tool geometries and CVD diamond coatings, wet machining is a frequently chosen alternative in order to discharge the heat generated by friction. Flat coolant or cryogenic coolant could be applied.

THE RIGHT TOOLS FOR CFRP MACHINING

For the machining of composites MAPAL has all necessary tools. Normally the use of flat milling and torus shapes Milling cutters is well recommended.