Fabricating and Cutting Thermoset Materials

ATLAS FIBRE

As the machining of plastic materials cannot be mastered in one setting, the same can be said, probably more so, of thermosets (FR4/G-10, G-11, phenolics). Glass epoxies and phenolics have traditionally been unfairly characterized as materials that many machine shops or fabricators avoid due to their dust, wear and tear on equipment and tools and the overall toughness of the material. To the contrary, with a little bit of practice and patience, most fabricators can master the art of thermosets. What follows is a guide to get you started in that process. Mastering these suggestions will not immediately make you an expert machinist of these materials but should significantly improve your skills.

Paper and fabric grades

Thermoset materials machine well with proper techniques. As a rule, they machine more readily than metals with standard machine tools such as those used for wood or metal fabrication.

For most machining operations, ordinary high-speed steel tools are satisfactory. However, where production quantity, speed or finish is important, carbide-tipped tools often prove more economical. Cutting tools must be kept extremely sharp to achieve accuracy and fine finish.

Thermosets are machined dry; cutting compounds and lubricants are not necessary. Cooling by air is preferable to the use of liquid coolants which are difficult to remove from finished parts. Machine operators should be cautioned to keep the temperature of the work below 302°F/150°C since temperatures above 302°F/150°C may distort the material. Cuttings are readily removed by suction.

Epoxy glass based grades

In many cases, the same machining operations employed in the fabrication of metals and wood may also be adapted to glass base grades. However, certain slight changes in tools and the use of proper speeds are necessary. Diamond or tungsten-carbide tools will give more satisfactory work with much longer, more economical life than high-speed tools.

Circular Sawing

Paper and fabric grades

Circular saws may be used for straight or angular sawing. When smooth edges are required or close tolerances are important, a hollow-ground circular saw without set should be used. For rough cutting, saws with set are satisfactory. The best results are obtained when the saw blade projects a minimum distance above the saw table.

When working with material up to 1" thick, 12" saws should be used. When working with material up to 2-1/2" thick, 16" saws should be used. It is important that all teeth be square, of the same height and free from burrs. The cutting edge should run directly toward or just back of the center hole. In both circular sawing and band sawing, the work should be fed as rapidly as possible without forcing it.

Epoxy glass based grades

A diamond impregnated wheel with copper body 1/16" thick and 12" diameter run at 3,000-3,600 rpm will give good results cutting dry with a good exhaust system. Material feed should be as fast possible without forcing the saw. Idling creates friction and heat, which cause excessive dulling and burning. A flood of water or water-soluble coolants on the work and wheel can be used when necessary to prevent overheating. Abrasive wheel cutting under water is also recommended.

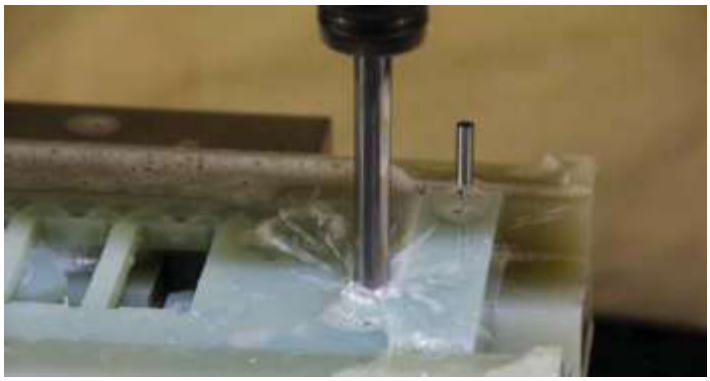
Turning

Paper and fabric grades

Ordinary high-speed tool steel can be used in finishing operations for all thermoset grades. However, carbide-tipped tools may prove more economical and will hold sizes more accurately from piece to piece. About .010" stock should be left for finishing. Thermosets can be turned at 400 surface feet per minute with high-speed tools and about twice as fast with carbides. Tools should be kept sharp, ground, with an included angle of 80° to 100° and with a 10° to 16° side clearance. Cutting should be done dry.

Epoxy glass based grades

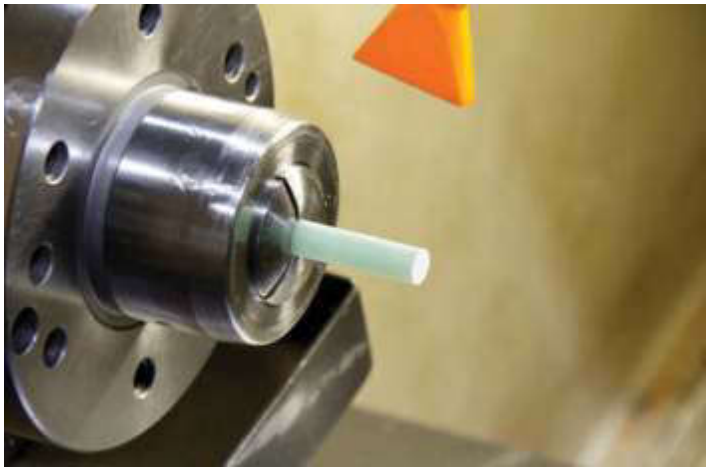
Conventional machining such as turning, boring and facing can be done on automatic screw machines, standard and production lathes and hand turret lathes. Carbide-tipped tools and cutters should be used with surface speeds below those used for paper base laminates. Tools should be ground with a zero rake and machining can be done dry with an exhaust system to remove dust. A coolant can be used, but it is not necessary.



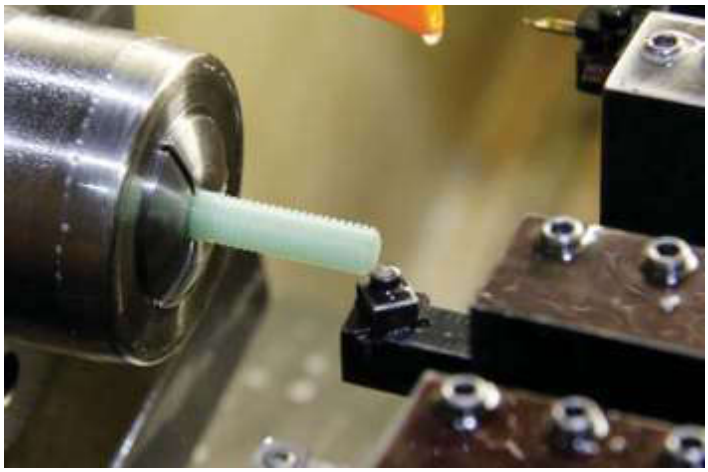
FR4 sheet being milled on a CNC milling machine.

Application	RPM	# Teeth	Diameter
Rough cut*	2150	100	16"
Smooth cut*	2150	100	16"
All purpose*	2860	100	12"
Tubing cuts	2860	100	12"

** These saws have .019" set. Other saws are hollow ground to prevent binding.*



FR4 Atlas Fibre sheet rod prior to turning on a CNC lathe.



The FR4 Atlas Fibre sheet rod after machining.

Milling

Paper and fabric grades

Standard tools may be used at speeds and feeds similar to those for bronze and soft steel. It may be more economical in spite of higher material cost to use carbide tools. The cutting angle of the mill will give better results if ground with a slight rake.

Epoxy glass based grades

Glass based laminates can be milled satisfactorily on any conventional metal-working milling machine. Carbide tipped tools should be used. Only climb or down milling should be practiced, as up milling will tend to delaminate the material.

Drilling and Tapping

Paper and fabric grades

A standard high-speed drill with lips backed off to provide plenty of clearance is satisfactory for all thermoset grades. However, for long production runs and deep holes, carbide-tipped drills give the best performance.

Drills should be lifted from the work frequently to prevent binding and excessive heating. The feed should be light and uniform and the speed of the drill should be considerably in excess of that used for soft steel. With tungsten-carbide tips, speeds may be as high as 16,000 rpm. Where possible, the material being drilled should be backed up with scrap thermoset or other soft material to prevent chipping out.

In drilling thermosets parallel to laminations, extra care must be taken to prevent splitting. The material should be clamped in a vise or between plates and the drill should be lifted more frequently to remove chips.

Holes 3/4" and larger may be drilled in the conventional manner using radial drill presses or the counter bore method in which a pilot hole is drilled first.

Drill size: Because of the nature of plastic material, the diameters of holes drilled in laminates are usually .002" under the drill size. Therefore, the drill selected should be at least .002" larger than the specified diameter of the hole. If the drill is being used dull, the hole size may be an additional .002" undersize, or a total of .004" less than the diameter of the drill.

The recommendations for drilling also apply to tapping. Taps used for metal are also suitable for thermosets. Tapping heads or tapping machines may be used and for production work, collapsible taps are available in sizes larger than 1 ¼".

Tap size

In tapping thermosets, high-speed taps .002" oversize should be used. The tap drill size should also be changed to .002" oversize to counteract the tendency of the drill to cut undersize. If the thread is to be used frequently, metal inserts should be used.

For threaded holes larger than 1/2" it is often more desirable to chase the thread on a lathe using a motor-driven cutter mounted on the tool post.

Epoxy glass based grades

When drilling glass based grades, a carbide drill should be used. The materials can be drilled dry with a good exhaust system to remove dust. A flood of water or wash-soluble coolants on the work and drill can be used when necessary to prevent overheating and dulling of drills. High-speed drills, nitrate treated, can be used, but must be sharpened more often. Care should be taken when sharpening that the drill is cut back far enough to the original body diameter of drill. Spindle speed for these grades is 4,800 rpm for 1/4" diameter drills.

The methods for tapping these materials are much the same as for tapping paper based laminated plastics. The abrasiveness may cause taps to cut very close to size, resulting in a tendency toward binding when backing out. Standard high speed steel taps can be used on short runs. For any sizeable quantity, carbide taps should be used. Taps should be purchased oversize. Coolant can be used, but is not necessary if a good exhaust system is available.

Threading

Paper and fabric grades

For threaded holes larger than 1/2" it is often more desirable to chase the thread on a lathe, using a motor-driven cutter mounted on the tool post. When cutting a 60° thread, it is always advisable to swing the compound reset on the lathe to a 30° angle. The tool is ground to cut on one side only.

For all other threads, standard methods are used with satisfactory results: the speed and feeds are similar to those used in threading soft steel.

Epoxy glass based grades

External threads and internal threads can be cut on a lathe with a carbide-tipped tool, dry. Fine cuts should be taken to give best results. A coolant can be used, but is not necessary.

Conclusion

In summary, the machining of glass epoxy/phenolic materials have always held certain misconceptions about how they can be fabricated. Hopefully this overview has given you some guidelines and new techniques to perfect your ability to work with thermosets.

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