# MACHINING OF COMPOSITE MATERIALS USING TRADITIONAL METHODS

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**ABSTRACT**

Composite materials are difficult to machine than metals mainly because they are anisotropic, non-homogeneous and their reinforcing fires are very abrasive. During machining, defects are introduced into the work piece, and tools wear rapidly. Traditional machining techniques such as drilling or sawing can be used with proper tool design and operating conditions. In this article is presented a review of traditional machining methods applied to organic and matrix composite.

**KEYWORDS:** composites, cutting, drilling, machining

## 1. INTRODUCTION

Composite materials are used extensively because of their higher strength to weight ratios and, when compared to metals, offer new opportunities for design. However, being non-homogenous, anisotropic and reinforced with very abrasive fibers, these materials are difficult to machine. Significant damage to the work piece may be introduced and high wear rates of the tools are experienced.

Traditional machining methods such as drilling, turning, sawing, routing and grinding can be applied to composite materials using appropriate tool design and operating conditions.

Drilling is the most common composite machining operation, since many holes must be drilled in order to install mechanical fasteners [1]. Poor hole quality accounts for an estimated 60% of all part rejections and since holes are drilled in finished products, part rejections due to poor hole quality prove very costly.

The mechanics of drilling composites materials will be examined along with special blade design parameters.

## 2. MECHANICS OF DRILLING COMPOSITEMATERIALS

The thrust and torque applied on a bit during drilling operations depend on speed, feed rate, tool geometry and tool wear.

Experiments [2] showed that thrust increases steadily until a constant value corresponding to steady drilling through the thickness of the laminate is reached, and is fallowed by a sharp drop as the tool exits the opposite side.(fig. 1)

A sharp decrease in normal force as the bit enters the work piece is always associated with the introduction of delamination by mechanical action of the tool peeling up the top layer of laminate [5].

Delamination of the top layer can also be produced by high thermal stresses generated by drilling, but, in that case, no discontinuities are observed in the normal force history.

Delamination near the exit sides is introduced when the tool acts like a punch separating the thin uncut layer from the remainder of the laminate. This action is associated with an almost instant drop in normal force from its steady value down to zero. Delaminations can be greatly reduced or eliminated by reducing feed rates near the end and using backup plates [6].

During drilling torque increases rapidly until the cutting edges of the tool are completely engaged and then increases linearly until a maximum value is reached, fallowed by a slight drop after hole completion.(fig.2)

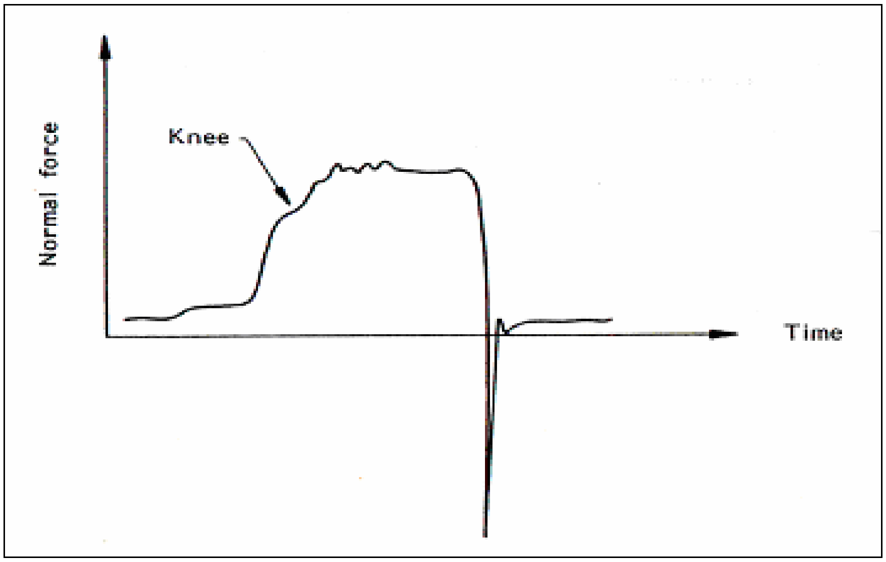


***Figure 1. Typical axial force history during drilling of composite laminates***

As drilling progresses, the tool is in contact with the side over an increasing area so that frictional forces at the interface create increasingly higher resistant torque.[3] After complete penetration has occurred only a small decrease in torque is observed which indicates that friction is the major contribution to total torque.

Maximum normal force and maximum torque both increase very significantly with the number of holes drilled.

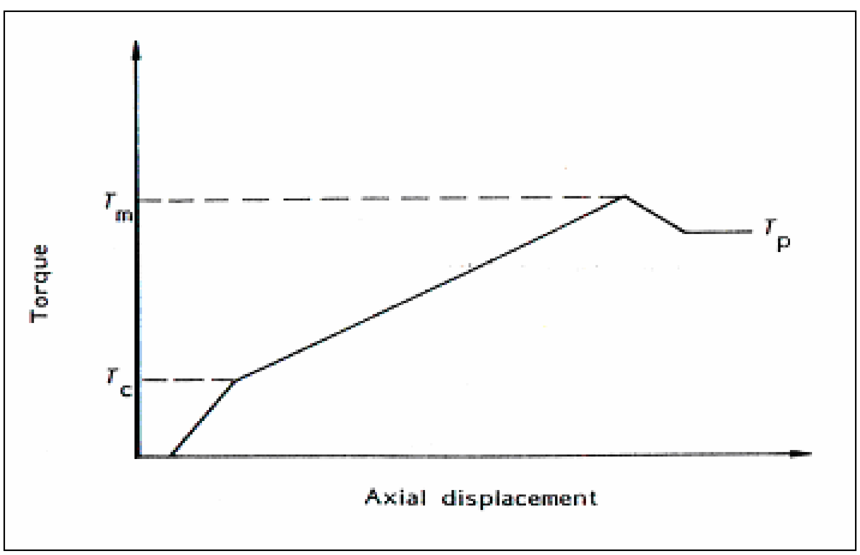


***Figure 2 Variation of torque during drilling***
***$T_c$-cutting torque; $T_m$- maximum torque; $T_p$-torque after penetration***

Using 8 mm split point carbide drills to drill 4.5 mm thick graphite-epoxy composite slabs at 2800 rev/min and a feed rate of 0.0152 mm/min, the variation of peak thrust was determined as a function of the number of holes drilled. [3,4,9,11]
Increases in thrust due to tool wear were reported in many investigations and were shown to be more important when drilling graphite-epoxy than with glass-epoxy due to the more abrasive nature of graphite fibers.
Higher normal forces usually introduce more damage to the work piece, particularly delaminations. However, the maximum torque or maximum normal force does not correlate well with surface finish.[3]
An analytical analysis of temperature distribution in the work piece and the tool when drilling laminated glass-epoxy printed circuit board showed good agreement with experimental results. Heat generated during drilling is distributed differently than for metals where, typically, 75% of the thermal energy is eliminated with the chip material, 7% is absorbed by the work piece and 18% by the tool.
For carbon-epoxy, the tool absorbs approximately 50% of the energy; the work piece and the chips absorb the remainder almost equally [8]. Temperatures as high as 200 $^{o}$C were reported near the hole.
Spatial and temporal gradients are strongly affected by the thermal conductivity of the material.
Smaller temperature gradients are observed in carbon-epoxy than in glass-epoxy or aramid-epoxy materials under the same conditions.
The upper limit on the cutting speed is limited by the risk of introducing thermal damage to the work piece materials, while a lower limit is governed by the surface quality which becomes poor as the fibers recede in front of the cutting edge.[7,10]
Typical values of cutting speeds and feed rates used for drilling composite materials are given in table 1

***Tabelul 1 Typical machining parameters for drilling composite materials***

| Workpiece material | Tool material | Hole diameter (mm) | Material thickness (mm) | Cutting speed (m/min) | Feed rate (mm/rot) |
|---|---|---|---|---|---|
| Graphite-epoxy | Carbide | 4,85 | 6,35 | 60,9 | 0,0254 |
| Glass-epoxy | HSS | - | 12,5 | 15,0 | 0,028 |
| Glass-epoxy | HSS | 8 | 1,2 | 0-40,2 | 20 -460 mm/min |
| Carbon-epoxy | Carbide | 3 | 10 | 33,0 | 0,05 |

## 3. DEMAGE INDUCED BY DRILLING

Several types pf damage are introduced during the drilling operations: matrix cratering and thermal alteration, fiber pullout and fuzzing, interlaminate cracks and delamination, in addition to geometrical defects commonly found in metal drilling.
Drill wear and delamination are both influenced by the type of drill used.[2]
A delamination factor δ can be defined as the ratio between the maximum diameter of the damage zone and the diameter of the hole: δ reaches an upper limit as the number of holes drilled increases. For a spiral point drill, the delamination factor tends towards 1.2 after just three holes.[2] For solid carbide split point drills, the delamination factor settles around 1.8 after five holes, while the High Speed Steal (HSS) split point drill settle at 2.5 after 4-5 holes.[12]
First infiltrating a liquid penetrant through the cut surface and measuring D, the width of the damage zone, with an optical microscope, determined the width of the damage zone in glass-epoxy laminates. D is shown to depend

on the ratio between the cutting speed $V_r$ and the feed rate $V_t$. A sharp decrease in damage width is observed first as $V_r / V_t$ increases.
The critical value, in the range of 100-150, is dependent of resin type, fiber format, extent of damage, however, may depend on material properties and lay-up.

## CONCLUSION

In this paper I have referred more to the study of composites with a polymeric matrix reinforced with glass-fiber. Generally, composites armored with glass-fiber or other materials, with a unidirectional orientation, are used on a large scale at the production of structures, piece binding elements, electrical isolation tapes because they have good behavior to mechanical stresses and a high mechanical resistance to weight ratio.
From the point of view of the advantages offered by these materials as: high toughness, relatively high temperature resistance, good mechanical resistance, high resistance to corrosion and wear, the question of why these materials are used on such a small scale in industry is raised. One of the problems they have is the one regarding their low machining property

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