OPTIMIZATION DRILLING PROCESS OF GLASS FIBER REINFORCED PLASTICS

NORHAIDA BINTI MOHAMAD NOOR

UNIVERSITI MALAYSIA PAHANG

ACKNOWLEDGEMENT

Politely I wish everybody in a good condition. Grateful sense goes to Allah, The Most Beneficent and The Most Merciful on His blessing until this thesis produced properly. With a deep sense of gratitude I would like to express my sincere thanks to my supervisor, En. Rosdi Bin Daud and for his attention to guide me on doing this project thesis as well and not forgotten to the En. Mohd Fadzil Faisae Bin Ab. Rashid and Pn. Noryanti Binti Muhammad who was always help me.

I am appreciates my parents supports, my siblings and my friends who involved during this project done. Thanks a lot. To mother and father, your pray is very meaningful to my life.

I had tried my best to apply the knowledge that you delivered and I hope this can show my full commitment about the project. I am also happy to present everybody who ever involved in one way or another, made significant contributions to various process of this project. I hope I can learn something from this project and everybody can understand all the input inside this thesis.

ABSTRACT

Fibre reinforced composites are widely recognized for their superior mechanical properties and advantages for applications in aerospace, defence and transportation sectors. The material that was being chosen for this research is glass fibre reinforced plastics. Drilling tests have been conducted on glass fiber-reinforced plastic composite glass fibre reinforced plastic laminates using an instrumented CNC milling center. Machining parameters such as type of drilling tool, feed rate, cutting speed, and their influence on the thrust force are investigated. Furthermore, the quality of the holes produced from the drilling process also must be considered with special attention paid to the delamination damage.The damage was seeing through optimal microscope. Kistler software was been using to get the trust force value as the output in this experiment. The Kistler Piezoelectric Dynometer was connected to the PC of CNC machine. The function is to measure the thrust force value. The delamination factor can be calculated by using their equation. By using SPSS software to get the equation, the equation that was being created is Multiple Linear Regression then come out with ANOVA analysis. This equation is to show that the significant of the variables when drilling glass fiber. After that, User-Defined was being used to optimize the parameter and get the optimal condition to drill glass fiber for minimized the damages.

Abstrak

Gentian yang kukuh diketahui mempunyai cirri-ciri mekanikal yang kuat dan mempunyai banyak aplikasi di dalam sector seperti pertahanan, pengankutan dan kapal terbang. Bahan yang digunakan di dalam untuk penyelidikan ini ialah gentian kaca plastik yang kukuh. Dengan menggunakan mesin kisar CNC, lubang dibuat pada gentian kaca plastik itu. Parameter mesin seperti perkakas untuk membuat lubang, kadar kepantasan mesin bertindak(makan), kelajuan pemusing dan daya tujahan juga turut dikaji. Selanjutnya, kualiti lubang daripada proses membuat alur tadi akan dikaji terutamanya pada kerosakan kawasan yang tidak berlapis. Kerosakan itu dilihat menerusi mikroskop optik. Perisian ‘Kistler’ digunakan untuk mendapatkan nilai daya tujahan. Kistler piezoelektrik dynometer disambungkan ke computer mesin CNC. Fungsinya adalah untuk mendapatkan nilai daya tujahan. Perisian SPSS adalah untuk mendapatkan formula, formula dihasilkan dari gandaan kemerosotan dan menghasilkan analysis perbezaan. Formula ini adalah untuk menunjukkan kaitan parameter semasa membuat lubang pada gentian kaca ini. Selepas itu, kaedah User-Defined digunakan untuk mendapatkan keadaan yang optimum untuk mengurangkan kerosakan pada lubang.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

Figure No. **Page**

LIST OF SYMBOL

P	Population regression
Y	Dependent variable
μ	Mean respond
σ	Standard deviation
ε	Error

LIST OF ABBREVIATIONS

Da	Diameter of delamination zone
Do	Diameter of tool of drill
Fd	Delamination factor
GFRP	Glass fiber reinforced plastic

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Advanced composite materials such as fiber reinforced plastics (FRP) are recognized as excellent materials for some structural components and are being increasingly used in various applications such as aircraft, ships, automobiles, machine tool and sports equipment, due to their excellent properties such as high specific strength, high specific stiffness, high damping, low thermal expansion, good dimensional stability and an unusual combination of properties not obtainable with metal alloys. As structural materials, joining of composite structures could not be avoided. The efficiency of mechanical joint is largely dependent on the quality of machined holes [1].

The drilling parameters and specimen parameters evaluated were spindle speed, feed rate, and types of drill. A series of experiments were conducted using CNC milling center to machine the composite laminate specimens at various cutting parameters. The experimental results indicated that the types of tool, feed rate and cutting speed are reckoned to be the most significant factors contributing to the delaminating and other damages.

Using Design of Experiment, DOE, there have 27 number of test. Three types of tool was been selected that is High speed steel HSS, coated carbide and solid carbide. For every tool, there have 9 test of hole with different of machining parameters. In this experiment the output is the thrust force and delamination. By using Piezoelectric Dynometer connected to the PC at CNC milling machine the value of thrust force and torque can get by install the Kistler software. The delamination can be analyzing using delamination factor. The delamination factor is the ratio of diameter delamination area to the diameter of hole. The size of diameter hole is equal to the diameter of drill 6mm.

Due to their anisotropy, and non-homogeneity, FRP cause some problems in drilling such as fiber breakage, matrix cracking, fiber/matrix debonding, fiber pull-out, fuzzing, thermal degradation, spalling and delamination. Among the defects caused by drilling, delamination is the most critical. Delamination can result in lowering of bearing strength and can be detrimental to the material durability by reducing the structural integrity of the material resulting in long-term performance deterioration [1]. The special attention damages to the hole quality is delamination, but in this experiment the other damages will be investigate.

Analysis of variance (ANOVA) is used to study the effect of process parameters on machining process. The purpose of the analysis of variance (ANOVA) is to investigate the design parameters significantly affect the quality characteristic of a product or process. To test the significant of the parameters on machining process the equation of the output must being created. Here only one output was been selected that is delamination factor, Fd. By using SPSS software, the Multiple Linear Regression equation will be created.

Damage that developed during drilling process has to simulate using User-Defined method. The optimization result will show the best condition to drilling glass fiber where at this condition the damages will be minimized.

1.2 Problem Statement

There is several problems from this research, normally to machining of fiber-reinforced composites is difficult due to diverse fiber and matrix properties, fiber orientation, inhomogeneous nature of the material. Thus, when drilling the fiber reinforced plastic composite may produce several kinds of damage. The most seriously is the delamination. To investigate the damage effects of drilling an optimization technique is employed. Appropriate control parameters are chosen to narrow the scope of study such as spindle speed, feed rate and three types of tools and the main outputs investigated are thrust force and delamination.

1.2 Objective

I. To get optimal condition for drilling glass fiber reinforced plastics.

II. To analyze the data of experiment by using Multiple Linear Regression

III. To analyze the damages occur at the hole with special attention is delamination.

1.3 Scope

A research about the damages at the hole of drilling glass fibre reinforced plastic composite and gets the optimal parameters to be used to drill glass fiber.

CHAPTER 2

LITERATURE RIVIEW

2.1 INTRODUCTION

To select cutting parameters for damage-free drilling in glass fiber reinforced composite material. The optimization objective includes the contributing effects of the drilling performance measures such as feed rate, spindle speed, damage at the surface, and drilling thrust force.

2.2 DRILLING PROCESS

Drilling of holes in composite materials is a very common process in the assembly of aerospace and automotive composite structures. With regard to the quality characteristics of drilled composites, some of the problems encountered include surface delamination, internal delamination, fiber or resin pullout, hole shrinkage, last ply damage, hole surface roughness, and higher tool wear due to abrasion by hard fibers. In order to minimize these machining problems, similar to metals, there is need to develop scientific methods to select cutting conditions for damage-free drilling of composite materials. Most previous work focused on optimization of parameters for machining metallic materials.

In order to overcome these difficulties it is necessary to develop procedures to select appropriate cutting parameters, due to the fact that an unsuitable choice could lead to unacceptable work material degradation.

Figure 2.1 shows that factors such as cutting parameters and tool geometry/material must be careful selected aiming to obtain best performance on the drilling operation, the best hole quality, which represents minimal damage to the machined component and satisfactory machined surface [1]

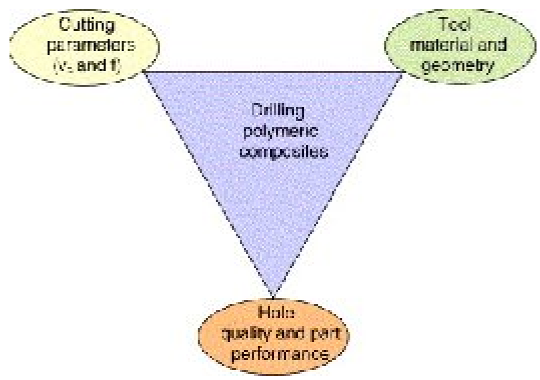

Figure 2.1 Principal aspects to be considered when drilling fibre reinforced plastics.

2.3 PARAMETERS for DRILLING FIBER REINFORCED PALSTICS

2.3.1 Spindle Speed

The speed of a twist drill is generally referred to as cutting speed, surface speed, or peripheral speed. It is the distance that a point on the circumference of a drill will travel in 1 min. A wide range of drill and drill sizes is used to cut various metals an equally wide range of speeds is required for the drill to cut efficiently. For every job, there is the problem of choosing the drill speed that will result in the best production rates and the least amount of downtime for regrinding the drill.
The most economical drilling speed depends on many variables:

(i) The type and hardness of the material
(ii) The diameter and material of the drill

(iii) The depth of the hole
(iv) The type and condition of the drill press
(v) The efficiency of the cutting fluid employed
(vi) The accuracy and quality of the hole required
(vii) The rigidity of the work setup

Although these factors are important in the selection of economical drilling speeds, the type of work material and the diameter of the drill are the most important. When references is made to the speeds at which a drill should revolve, the cutting speed of the material in surface feet per minute (sf/min) or meters per minute (m/min) is implied unless otherwise stated. The number of revolutions of the drill necessary to attain the proper cutting speed for the metal being machined is called the revolutions per minute (rpm). A small drill operating at the same rpm as larger drill will travel fewer feet per minutes, it naturally would cut more efficiently at higher number of rpm [2].

The effect of the machining parameters is another important aspect to be considered. Figure 3 shows the reported cutting parameters that are cutting speed and feed rate typically employed when drilling polymeric composites using high speed steel (HSS) and tungsten carbide (WC) drills. It can be seen that cutting speeds from 20 to 60 m/min are usually employed. Cutting speed is not a limiting factor when drilling polymeric composites, particularly with hard metals, therefore, the use of cutting speeds below 60 m/min may be explained by the maximum rotational speed of conventional machining tools, since drill diameters above 10 mm are rarely reported. Another reason for keeping cutting speeds below 60 m/min may reside in the fat that higher cutting speed values lead to higher cutting temperature, which in turn may cause the softening of the matrix [1].

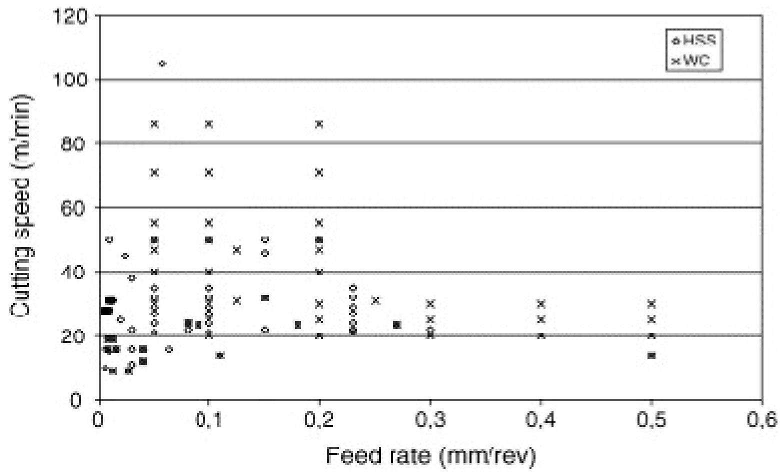

Figure 2.2 Cutting speeds and feed rates typically employed when drilling polymeric composites with high-speed steel (HSS) and tungsten carbide (WC) drills.

2.3.2 Revolution per minute

To determine the correct number of rpm of a drill press spindle for a given size drill, the following should be known:

(i) The type of material to be drilled

(ii) The recommended cutting speed of the material

(iii) The type of material from which the drill is made

Formula (Metric)

$$Rpm=CS(m)/\pi D(mm)$$

It is necessary to convert the meters in the numerator to millimeters so that both parts of the equation are in the same unit. To accomplish this, multiply the CS in meters per minute by 1000 to bring it to millimeters per minute.

$$Rpm= CS \times 1000/ \pi D$$

Not all machines have a variable speed drive and therefore cannot be set to the axact calculated speed. By dividing π(3.1416) into 1000, a simplified formula is derived that is accurate enough for most drilling operations.

$$Rpm= CS \times 320/D$$

2.3.3 Feed Rate

Feed is the distance that a drill advances into the work for each revolution. Drill feeds may be expressed in decimals, fractions of an inch, or millimeters. Since the feed rate is a determining factor in the rate of production and the life of the drill, it should be carefully chosen for each job. The rate of feed is generally governed by:

(i) The diameter of the drill
(ii) The material of the workpiece
(iii) The condition of the drilling machine [2]

Investigated the influence of feed rate on the delamination of a glass fibre reinforced plastic and found that under low feed rates delamination does not take place. When feed rate is increased the actual back rake angle becomes negative, thus pushing the work material instead of shearing and causing its delamination [3]. Refer to the Figure2.2, whereas feed rate values lower than 0.3 mm/rev are frequent. The use of feed rates below 0.3 mm/rev may be associated to the delamination damage caused when this parameter is increased [1].

2.3.4 Thrust force and toque

We found that there is a delay between the response for thrust force and torque, after which the former reaches a maximum value. From this point the thrust force value is reduced probably due to the softening of the matrix caused by friction and the torque increases due to the fact that the last fibres are not sheared, but entangled in the drill. They also noticed that the effect of cutting speed on thrust force is negligible, whereas torque increases with cutting speed. Surface roughness was not significantly affected by both cutting speed and feed rate [4].

To machining of glass fibre reinforced plastics composites produced using distinct matrix materials as a epoxy and polyester resins and reinforcing shapes like a chopped, cross winding, continuous winding and woven. We found that in contrast to other reinforcing shapes, when drilling the cross winding composite a gradual decrease in thrust force was observed at the drill exit, resulting in a surface without delamination. When machining the woven composite with different matrix materials, the matrix had a negligible effect on thrust force but torque was higher when drilling the polyester composite. Increasing cutting speed resulted in lower thrust force and torque due to the higher temperatures produced by the increase in heat generation associated with the low coefficient of thermal conduction together with the low transition temperature of plastics [5].

The experiment involved drilling of a glass fibre reinforced plastic with a cemented carbide drill (1 mm diameter). We found the thrust force is drastically reduced when the hole is pre-drilled to 0.4 mm or above [6].

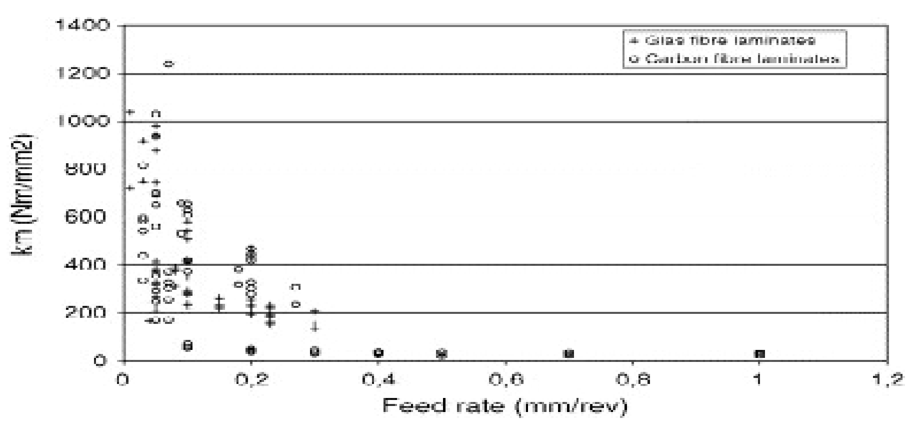

Figure 2.3 Influence of feed rate on the specific cutting coefficient (k_f) associated to the thrust force.

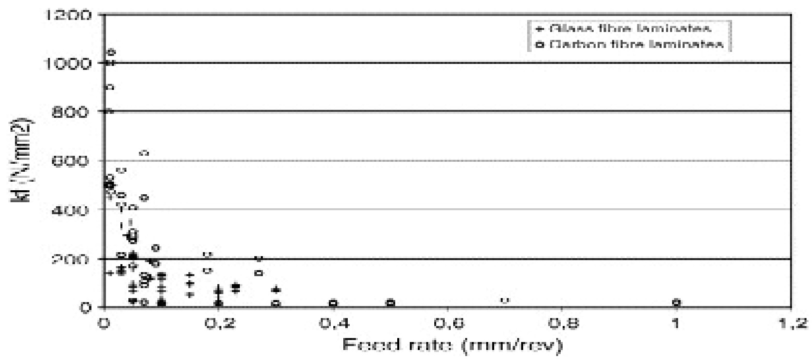

Figure 2.4 Influence of feed rate on the specific cutting coefficient (k_m) associated to torque.

Figure 2.3 and Figure 2.4 show the influence of feed rate on the specific cutting coefficients related to the thrust force (k_f) and torque (k_m), respectively, calculated from Equation,

$$k_f = \frac{2F_f}{fd}$$

$$k_m = \frac{8B}{fd^2}$$

Where:

(i) F_f is the thrust force (N)
(ii) f the feed rate (mm/rev)
(iv) d the drill diameter (mm)
(v) B is the torque (Nmm)

Noticed that from Figure 2.3 feed rate is increased, the k_f values decrease at higher feed rates. The number of fibres to be sheared will be reduced. Differences in the k_f values obtained for the same feed rate are due to differences in drill geometry, reinforcing material, volume fraction, fibre orientation and laminate thickness. Figure

2.4 show the influence of feed rate on k_m for glass and carbon fiber reinforced plastics. Similarly to Figure 2.3, it can be seen that for the same reasons previously explained, the k_m values decreases drastically as feed rate is elevate.

2.4 MEASUREMENT OF THRUST FORCE AND TORQUE

Drilling tests were performed without backing plate and cutting fluid on convention radial drilling machine. While the variable feed technique was implemented on CNC milling/drilling machine. To neglect the effect of drill wear each hole was drilled using a new standard HSS, coated carbide and carbide drills with 6 mm diameter. Thrust force and torque was measured using two-component dynamometer, based on strain-gage sensor Figure 2.5. The dynamometer was connected by a data acquisition system that assembled in PC to monitor and acquire the test data. The data was stored as an ASCII data file in the PC. These data represent the relationship between the machining time and the electrical output signals from the strain gages that forming the Wheatstone-bridges. The electrical output signals (volt) for thrust force and torque were calibrated using known thrust and torque. The variation of thrust force and torque with machining time were plotted as wave forms, while the average value of the maximum five peaks in these wave diagrams were used to investigate the influence of cutting variables on thrust force and torque. At least two testes were implemented for each cutting variables. The drilling variables are: feed rate, f =1000, 2000, 3000 mm/min and rpm= 1000, 3000, and 5000 [5].

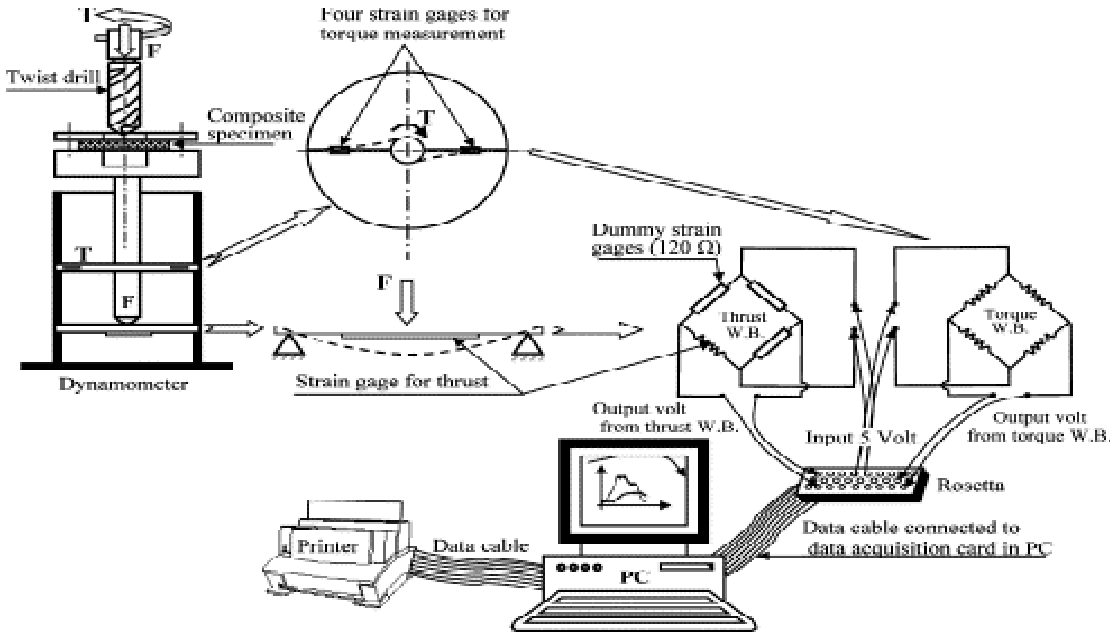

Figure 2.5 Set-up for measurements the thrust force and torque.

2.5 TOOL MATERIAL AND GEOMETRY

Tool geometry is a relevant aspect to be considered in drilling of fiber-reinforced plastics, particularly when the quality of the machined hole is critical. Finally, Figure 2.2 shows that tungsten carbide tools are preferred when drilling at higher cutting speeds and at higher feed rates [1]. The influence of using a trepanning tool on thrust force and torque when drilling glass fibre reinforced plastic showed that the performance of the trepanning tool was superior to the conventional twist drill, resulting in 50 and 10% of thrust force and torque [7]. Beside that, the effect of the drill diameter on the thrust force and torque at a high speed twist drills with diameters of 8, 9, 10, 11, 12, and 13 mm to machine a glass fibre reinforced plastic using a constant rotational speed of 875 rpm and feed rates of 0.1–0.23 and 0.5 mm/rev. The results indicated that thrust force and torque increased with drill diameter and feed rate, due to the increase in the shear area. Increasing cutting speed also resulted in higher thrust force and torque, however, not to the same extent as when feed rate is elevated [4].

Figure 6 presents the results of this survey with regard to the tool materials and geometries used to drill polymeric composites. It can be seen that high-speed steel (HSS) and tungsten carbide (ISO grades K10 and K20) are equally used as tool materials, while polycrystalline diamond (PCD) is seldom tested. As far as the tool geometry is concerned, it can be seen that the use of drill with special geometry such as core drills, multi-facet drills, candle stick and parabolic drills together with drills with modified geometry like a various chisel lengths and rake, clearance, point and helix angles are preferred when drilling with tungsten carbide tools. On the other hand, when using high-speed steel drills the use of standard twist drill and drills with special geometry are similar.

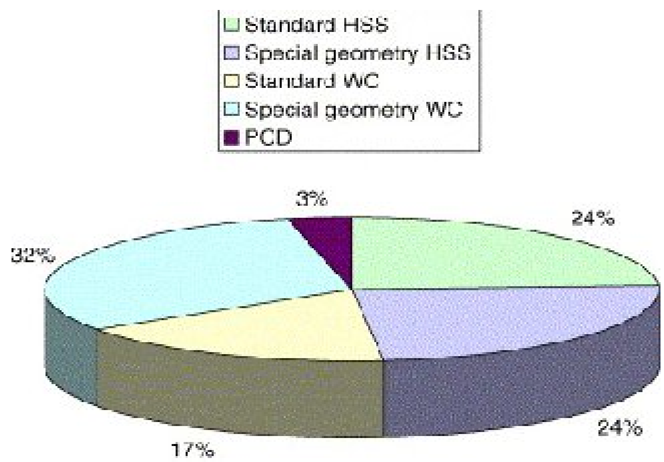

Figure 2.6 Tool materials used to drill polymeric composites.

2.6 HOLE QUALITY AND PART PERFOMANCE

In the drilling of reinforced plastics the quality of the cut surfaces is strongly dependent on the appropriate choice of drilling parameters. The aim of this work is to clarify the interaction mechanisms between the drilling tool and material. Drilling tests were carried out on glass-polyester composites using standard HSS tools. Drilling was interrupted at preset depths to study damage development during drilling. The specimens, polished by a metallographic technique, were examined by optical microscopy to identify any damage. The results obtained are useful in describing the