# INFLUENCE OF DRILL GEOMETRY
# ON HOLE QUALITY IN DRILLING
# HYBRID CARBON FIBRE REINFORCED POLYMER (HCFRP)

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)



by

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I hereby, declared this report entitled "influence of drill geometry on hole quality in drilling hybrid carbon fibre plastic (HCFRP)" is the result of my own research except as cited in references.

Signature : ……………………………………….
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# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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# ABSTRAK

Penggerudian adalah salah satu proses penting dalam industri pembuatan aeroangkasa kerana toleransi ketat yang diperlukan untuk pengikat seperti rivet dan bolt untuk memasang bahagian tertentu untuk pemasangan akhir. Secara amnya, bahagian ini diperbuat daripada Plastik Bertetulang Gentian Karbon (CFRP) tetapi baru-baru ini bahan yang lebih maju seperti plastik Bertetulang Gentian Karbon Hibrid (HCFRP) digunakan dan ia menggalakkan nisbah kekuatan kepada berat yang lebih tinggi dalam aplikasi aeroangkasa. Walau bagaimanapun, salah satu aspek yang paling sukar dalam pemesinan polimer tersebut ialah kualiti lubang gerudi yang kurang baik yang mengurangkan kekuatan komposit, mengakibatkan penolakan komponen semasa pemasangan. Kajian ini bertujuan untuk menyiasat pengaruh geometri mata gerudi terhadap kualiti lubang gerudi dan mencari geometri mata gerudi yang optimum dalam menggerudi plat HCFRP melalui simulasi analisis unsur terhingga (FEA) yang dijalankan menggunakan perisian Ansys. Reka bentuk eksperimen iaitu kaedah tindak balas permukaan yang digunakan untuk mengenal pasti geometri gerudi terbaik dengan menggunakan input berbeza sudut titik dan sudut heliks dengan menggunakan parameter pemesinan tetap. Keluaran bagi penyelidikan ini adalah kawasan delaminasi yang merangkumi kawasan terdelaminasi pada bahagian atas, kawasan terdelaminasi pada bawah dan serta daya tujah semasa proses penggerudian. Berdasarkan hasil simulasi, sudut titik 120° dan sudut heliks 30° menghasilkan lubang yang paling tepat dengan delaminasi lebih kecil di atas dan delaminasi kecil di bawah. Daya tujahan yang diukur adalah pada tahap sederhana kerana bahan dan parameter tetap. Akhir sekali, geometri gerudi optimum untuk menggerudi bahan HCFRP adalah pada sudut titik 135° dan sudut heliks 28.81°.

# ABSTRACT

Drilling is one of the crucial processes in aerospace manufacturing industry due to the tight tolerances required for fasteners like rivets and bolts to attach certain parts for final assembly. Generally, these parts are made from Carbon Fibre Reinforced Plastic (CFRP) but recently more advanced material such as Hybrid Carbon Fibre Reinforced plastic (HCFRP) is utilized, and it promotes higher strength to weight ratio in aerospace application. However, one of the most difficult aspects of machining such polymers is the poor quality of the drilled holes which reduces the composite strength, resulting in component rejection during assembly. This study intends to investigate the influence of drill bit geometry on drilled hole quality and to the find optimal drill bit geometry in drilling HCFRP plates through simulation of finite element analysis (FEA) which was conducted using Ansys software. The design of experiment which is the surface response method is used to identify the best drill geometry by using different inputs of point angle and helix angle by using constant machining parameters. The output for this research is the delaminated area which includes the peel up delaminated area, the push down delaminated area and as well as the thrust force during drilling process. Based on the simulation result, the point angle of 120° and helix angle of 30° produces the most accurate hole with lesser peel up delaminated area and push down delamination area with the medium level of thrust force. Furthermore, the optimal drill geometry to drill HCFRP material is at the point angle of 135° and helix angle of 28.81°.

# DEDICATION

For my family and friends

for giving me moral support, cooperation, encouragement, and understandings

Thank You So Much & Love You All Forever

Last but not least, I wanna thank me

I wanna thank me for believing in me

I wanna thank me for doing all this hard work

I wanna thank me for having no days off

I wanna thank me for, for never quitting

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First and foremost, praises and thanks to the God, for the blessings that have showered to me to complete my final year project as successfully. I have taken efforts in this project.

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| | |
|---|---|
| HCFRP | Hybrid Carbon Fibre Reinforced Plastic |
| CFRP | Carbon Fibre Reinforced Plastic |
| FRP | Fibre Reinforced Polymer |
| CFRP/Ti | Carbon Fibre Reinforced Plastic and Titanium |
| CFRP/Al | Carbon Fibre Reinforced Plastic and Aluminium |
| SEM | Scanning Electron Microscopy |
| TIAlN | Titanium Aluminium Nitride |
| MQL | Minimum Quantity Lubrication |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| m | - | Metre |
| mm | - | Millimetre |
| D | - | Diameter |
| Fd | - | Delamination Factor |
| D max | - | Maximum Diameter |
| mm/rev | - | Millimetre per Revolution |
| $\theta$ | - | Point angle |
| $\psi$ | - | Helix angle |
| m/min | - | Metre per minute |
| Vc | - | cutting speed |
| mm/min. | - | Millimetre per minute |
| rpm | - | Revolution per minute |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

The usage of hybrid composite for the design of high-added-value components has increased, especially in the aerospace industry. In addition, with recent advancements in material science and technology, the aerospace industry is trying to utilize more composite materials in various structures and components. Composites are frequently combined with other materials to create a hybrid construction with higher strength-to-weight ratios than can be achieved with materials (Xu et al., 2016). In this context, Hybrid CFRP laminates such as layers of titanium alloy and aluminum alloy are widely used in aircraft fuselage, stabilizers, and wings due to their higher strength, higher fatigue resistance, and higher resistance to crack propagation to the bolt joints.

On the other side, a typical wide-body aircraft requires at least 55,000 holes for fabrication and assembly. Due to the numerous holes procedure, the cost of drilling processing materials can impact the entire production cost of an aircraft. (Gu et al., 2012). Holes must fulfil the specifications of aircraft manufacturers. The assembling process of HCFRP requires joining by bolt and nuts. It is necessary to drill multiple holes, which may pose several problems due to the inhomogeneous elements that make up the fiber and matrix structures layers. (Angelone et al., 2021) The drilling of many holes and precise drilling control are essential to attain undamaged pieces to ensure aircraft safety and reliability.

Drilling holes in polymeric composites results in damage around the hole edge, high-stress concentration, and delamination at the hole's entry and exit. Holes in composite constructions may become a possible cause of fracture formation or propagation. (Ilmiah, 2019).

This research aims to study the influence of drill geometry on hole quality in drilling hybrid Carbon Fibre Reinforced Plastic (HCFRP). Most of the finite element drilling research was performed utilizing CFRP. However, drilling HCFRP material has not yet been subjected to a finite element study. Therefore, it is crucial topic that need to explore in order to get a strong understanding on roles of different drill bit geometry in drilling HCFRP plate in order to obtain minimal amount of delamination and more accurate hole quality.

## 1.2 Problem Statement

In the aerospace industry, drilling is one of the most significant operations before the components assembly process. In the aerospace industry, delamination is one of the most severe defects generated by drilling causes product rejection.(Boccarusso et al., 2019) Delamination causes poor assembly tolerance and affects the material's structural integrity. Peeling the laminate on the top layer and pushing action on the thin uncut layer at the bottom are the two most essential processes in delamination. In addition, cutting speed and feed, drilling tool shape, tool material and coating also have a significant impact on the quality of the hole. The geometry of the drilling tool plays an important role in reducing surface damage, delamination, and tool performance. However, regular drills can damage composites, so a suitable drill will produce high quality and accurate drills.(Panchagnula & Palaniyandi, 2018) The poor quality of the drilled holes will affect the material performance and reduce the life of the assembly process. The strength and fatigue life of the holes have been severely decreased due to drilling defects. The quality of the hole influences the efficiency and lifespan of manufactured parts in aerospace. The drilling process parameters and drill bit should be selected appropriately to decrease delamination without losing productivity. (Goutham et al., 2021). The Figure 1.1 shows the delamination when drilling.

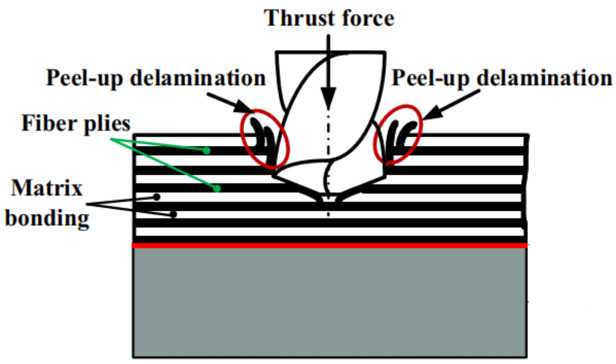


Figure 1.1: Delamination when drilling.

Thus, this research is to study the influence of drill geometry on hole quality in drilling hybrid Carbon Fibre Reinforced Plastic (HCFRP) in the aspects of delamination ratio, surface roughness, force, and tool wear for the development of new high-performance drill design for effectively drilling HCFRP aerospace parts.

## 1.3 Objectives

The objectives are as follows:

a) To investigate the effects of drill bit geometry on drilling performance of HCFRP.

b) To find the optimal geometry of the drill design for reducing delamination of the drilled holes.

## 1.4 Scopes of the Research

The scopes of research are as follows:

a) The study focuses on proposing the best twist drill geometry to drill HCFRP plates by using ANSYS software.
b) HCFRP used is a model of CFRP/AL in ANSYS software.

c) The drilling performance covers on finding delaminated area and hole accuracy of drilled holes.

d) The drill bit geometry that used in this research is limited to point angle and helix angle with fixed cutting speed and feed rate.

## 1.5 Significance of Study

This research attempts to determine the optimal drill geometry to drill HCFRP plates. This study aims to optimize the surface quality of the drilled plate for easier assembly and mechanical joining process in the future. The holes of prepared material must follow appropriate specifications for maintaining a longer life cycle of the component.

Since the HCFRP is expensive material in the market, it is essential to reduce the waste of materials in the aerospace industry. If the drilled material has a defect like delamination, irregular surface roughness, it will produce unwanted waste. Thus, this study is essential as it will reduce material waste towards green manufacturing.

Other than that, this research will be beneficial for the aerospace industry. It will improve the hole quality of drilling and reduce unwanted costs such as tooling, scrap, and inventory. Moreover, the finding of these further studies will be beneficial for future researchers to develop many new ideas.



## 1.6 Organization of Report

Chapter 1 is about the background of the study of that project that has been conducted. Then, the problem statement was identified based on previous research that has been undertaken. The project's objectives are also a roadmap for completing this research. The scope of the project, which is the study limitation, has been stated in this chapter. Finally, the significance of the study is said to show how important this research is to the aerospace industry.

Chapter 2 is about the literature review. It includes an overview of the literature on the project's background and important details related to the research. It is basically about the effects of hole quality of the drilling HCFRP material, delamination in HCFRP, the process of drilling laminate composite, and other relevant information related to the project.

Chapter 3 represents methodology. This chapter focuses on the method applied in this project to achieve the objective and the research's cope. It contains the planning and flow chart of conducting this research.

Chapter 4 is about results and discussion. All the measurements and data were collected and will be analysed. All the charts, tables, graphs are shown and explained for better understanding. The presentation of all data will be discussed in this chapter.

Chapter 5 is about the conclusion of this project. It summarises all the goals and objectives met and the suggestions for improvement for future research on this research stated.

## 1.7 Summary

Hybrid Carbon Reinforced Plastic (HCFRP) is widely used in aerospace. Since the material is formed layer by layer, it is not easy to perform drilling. It may produce some defects in drilling, such as delamination, tool wear, and it is not easy to achieve the quality surface needed for accurate assembly or joining of other components. This study is about finding optimal drill bit geometry for efficiently drilling HCFRP aerospace components, investigating the impact of drill geometry on hole quality in hybrid Carbon Fibre Reinforced Plastic (HCFRP) in terms of delamination ratio, force, and tool wear. Therefore, this study is essential to help reduce the impact of drilling on the workpiece and save cost by reducing the amount of waste produced.

# CHAPTER 2

## LITERATURE REVIEW

This chapter will provide a literature review about hybrid composite materials. The drilling process included drilling geometry, hole quality, drilling hybrid carbon-reinforced polymer, cutting parameter of drilling HCFRP. Then more studies regarding difficulties in drilling HCFRP such as delamination, burr formation, and tool wear are presented in this section. Finally, this chapter covers the analysis technique used by previous researchers.

### 2.1 Hybrid Composite Materials

Composite materials are made up of two or more macro elements that consist of elements and material content but are insoluble in one another. Due to its appealing features, such as high specific stiffness, high strength, and high corrosion resistance, advanced composite materials such as a fiber-reinforced polymer (FRP) have been widely used in structural components. There are two types of composite material is Carbon-reinforced polymer laminate and glass-reinforced polymer laminate (Ajith, 2020). In this context, the term "hybrid" refers to a composite of more than one type of matrix or fiber. Hybrid composites can extend the variety of qualities achievable using composite materials while also being more cost-effective than traditional or advanced composites. Hybrids have distinct characteristics that can satisfy design requirements more cost-effectively than advanced or traditional composites. By utilizing the advanced hybrid materials, the component's strength, stiffness, weight, enhanced fracture toughness, and impact resistance can be improved according to the design requirement. (Durão, 2005) .The Figure 2.1 shows the construction of hybrid composite material.

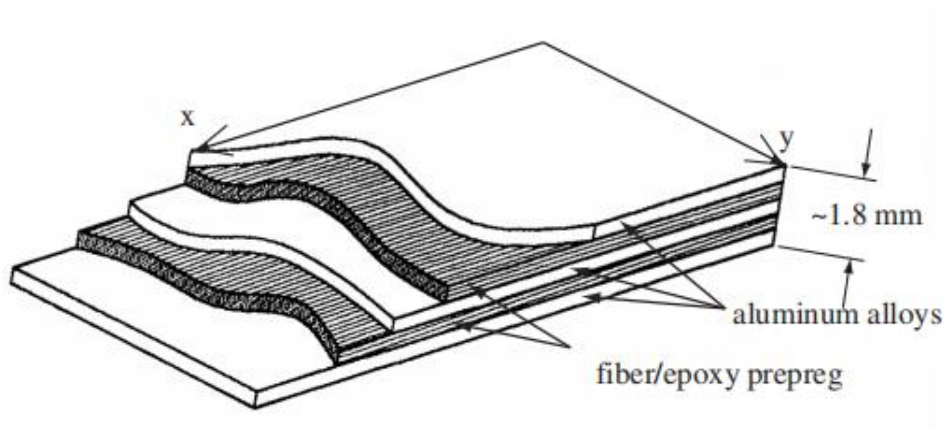


Figure 2.1: Configuration of hybrid composite material (Cocchieri et al., 2006).

In this context, fiber materials such as carbon fiber reinforced polymer can be combined with the metals such as aluminum or titanium to form a hybrid carbon-reinforced polymer (HCFRP). In other words, the term CFRP/Al stacks can be used since the material is stacked up layer by layer. (Seeholzer et al., 2021). Other than that, the term 'CFRP/Al hybrid laminates' is used as an example of HCFRP material. (Bellini et al., 2019)

The Hybrid Carbon Reinforced polymer is characterized by heterogeneous properties, anisotropy, and brittle, affecting machinability. CFRP and metallic components are often drilled in stacks to guarantee appropriate hole alignment during the subsequent fastening operation. (B. Wang et al., 2017) and it is widely applicable in the aerospace industry. Therefore, achieving accurate dimensional tolerance and assuring optimal assembly performance have become challenging issues in the aerospace industry. Since the research focuses on drilling HCFRP, significant literature will be explained in the following segments of the report.

## 2.2 Drilling

Drilling is commonly done using a rotating cylindrical tool, two cutting edges on one end and one on the other. The tool used for drilling is a drill bit. The rotating drill feeds into the stationary work component parallel to the machine axis, forming a hole where the drill diameter specifies the dimension. Feed is the vertical movement rate, and it is measured in millimetres per revolution. The equation below is to feed rate, fr, which is given in millimetres per minute. (Durão, 2005)

$$f_r = f \times N$$

The cutting speed of the drill can be calculated by using the equation below:

$$v_{c} = \pi DN/1000$$

### 2.2.1 Drill Geometry

The drill bit has two spiral flutes with the helix angle of 20˚,25˚,30˚. The primary function of the spiral flute is to expel the chips. The drill bit tip usually is in conned shape. The point angle is found on the head of the drill bit. The angle is calculated by measuring the distance between the two significant cutting edges at the top of the edges. Point angle is essential in centering twist drills. Usually, the point angle of the drill bit is around 118˚. This angle significantly impacts how the drill penetrates the material until it reaches its maximum diameter. (Aamir et al., 2019). The Figure 2.2 shows the geometry of the twist drill.



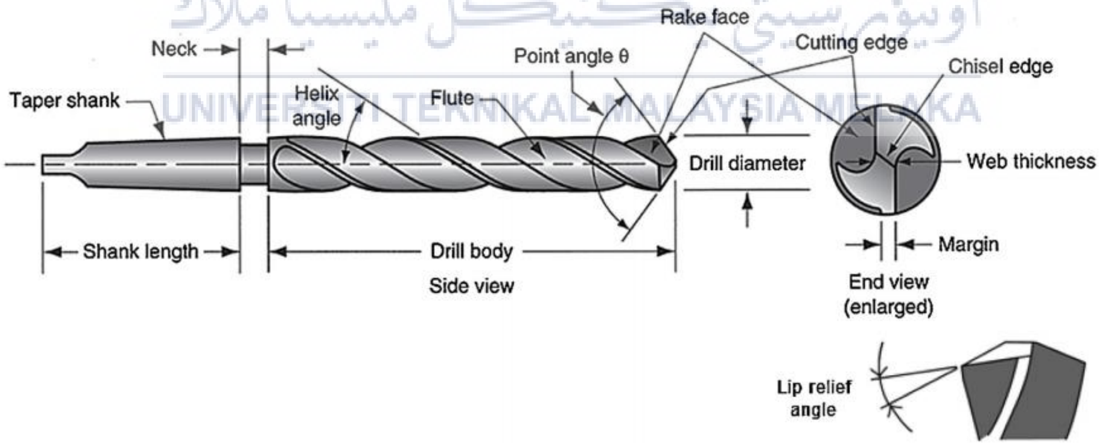


Figure 2.2: Geometry of the twist drill.

The cutting edge must be smaller in radius to minimize the defects from unstable cutting and avoid unexpected damage creation to the workpiece. Smaller contact lengths can be obtained by increasing the clearance angle. Small amount of lip clearance is needed to drill hard material but for soft material higher lip relieve angle is required. Normally the range of lip relieve is ranging from 8˚ to 24˚. (Aamir et al., 2019)

The helix angle of the cutting tool should be as small as possible to reduce the formation of burrs at the entrance and exit of the hole. Other than that, if the helix angle is small, the fiber twists in the direction it is supported, and the fiber is cut correctly. If the helix angle is large, the fibers will not be supported by the twist at the end of the hole, and significant burr formation is expected. However, if the helix angle is too small, it may pose difficulty in chip evacuation. The point angle should be as small as possible to reduce the axial force component of the cutting resistance. Point angle is mainly involved in the formation of delamination. However, the drilling tool length and machining cycle time can be significantly longer if the point angle is too small. In addition, significant radial force components can lead to fiber segment breakage at the edges of the hole. (Geier et al., 2020)

### 2.2.2 Hole Quality

The Figure 2.3 shows that hole quality criteria include burr formations, surface roughness, circularity, and hole size. Poor hole quality in final assembly causes a high rejection rate due to poor tolerance and allowance.

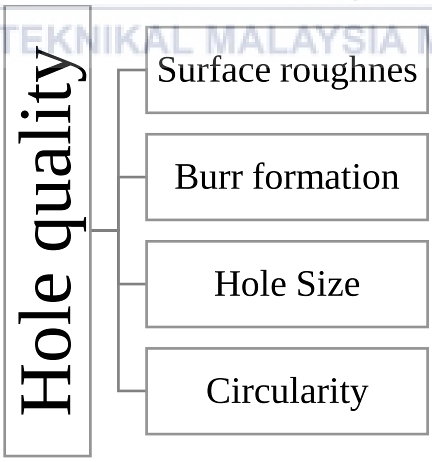


Figure 2.3: Characteristics of hole quality.

Surface roughness is a measurement of a workpiece's surface quality that may be used to assess surface imperfections caused by drilling operations. High surface roughness in drilled holes generates excessive wear in the material. (Xu et al., 2021) As a result, it will