OPTIMIZATION OF MACHINING PARAMETER IN DRILLIING CARBON FIBER REINFORCED PLASTIC (CFRP)

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

by

LINGGES A/L KUMARAN

B051810055

970313-10-6461

FACULTY OF MANUFACTURING ENGINEERING

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DR. MOHD SANUSI BIN ABDUL AZIZ
Pensyarah Kanan
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

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I hereby, declared this report entitled "Optimization of machining parameter in drilling Carbon Fiber Reinforced Plastic (CFRP)" is the result of my own research except as cited in references.

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Author's Name : LINGGES A/L KUMARAN

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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:

……………………………………………………

(Supervisor Name)

DR. MOHD SANUSI BIN ABDUL AZIZ
Pensyarah Kanan
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

ABSTRAK

Oleh kerana beratnya yang ringan, bahan komposit boleh menggantikan komponen logam dalam fiuslaj dan struktur pesawat, membantu mengurangkan penggunaan bahan api pesawat. Plastik bertetulang gentian karbon (CFRP) terdiri daripada berbilang komposit bahan yang disusun dalam pemasangan lamina bertetulang dengan kualiti bahan yang berbeza-beza di seluruh struktur. CFRP mempamerkan mekanisme kerosakan penggerudian yang meluas disebabkan oleh struktur berlapis dan anisotropi semasa pemprosesan, delaminasi secara berterusan dikaitkan dengan tujahan. Ia boleh membawa kepada kawasan delaminasi yang besar di pintu masuk dan keluar lubang gerudi. Kurangkan kawasan delaminasi dan tujahan dengan menentukan parameter optimum untuk operasi penggerudian, termasuk kelajuan pemotongan mesin, kadar suapan dan kedalaman mematuk. Dengan menggunakan kelajuan gelendong berubah-ubah, kadar suapan dan kedalaman mematuk dari 1,500 hingga 3,000 rpm, 0.02 hingga 0.06 mm/rev, dan 2 hingga 4 mm, daya tujah dan kawasan delaminasi di lubang masuk dan keluar lubang telah disiasat semasa pemesinan. Eksperimen telah dilakukan secara sistematik menggunakan reka bentuk faktorial penuh. Pada peringkat ini, model matematik tujahan, kawasan stratifikasi masuk dan kawasan stratifikasi alur keluar dibangunkan. Selain itu, analisis varians (ANOVA) telah dilakukan untuk menentukan kepentingan model. % ralat kawasan tujahan dan delaminasi di pintu masuk dan keluar lubang ditentukan oleh tiga eksperimen pengesahan. Mengikut keputusan, ralat kawasan berlapis dan tujahan adalah kurang daripada 10%. Keadaan optimum untuk kawasan tujahan dan delaminasi minimum didapati pada kadar suapan 0.02 mm/rev, kelajuan pemotongan 1,500 rpm, dan kedalaman mematuk 2.787 mm.

ABSTRACT

Composites are a substitute for metal components in airliner bodies and structures due to their light weight, which helps to reduce aircraft fuel consumption. One of them is, Carbon Fibre Reinforced Plastic (CFRP) which consists of several composite of material stacked in reinforced laminates component form, with varying material qualities throughout its structure. CFRP shows a wide range of drilling damage mechanisms because of its layered structure and anisotropy. During machining process, delamination is constantly linked to the thrust force that's leads to a larger area of delamination at the entry and exit of the drill hole. This research aims to decrease the delamination area and thrust force by determining the optimal parameters for the drilling operation, including machine cutting speed, feed rate, and pecking depth. The thrust force during machining and delamination area at hole entry and exit are investigated by using variable spindle speed, feed rate and pecking depth from 1,500 to 3,000 rpm, 0.02 to 0.06 mm/rev and 2 to 4mm, respectively. The experiments were conducted systematically using a Full Factorial design. During this phase, the mathematical models for thrust force, entry delamination area, and exit delamination area were developed. Additionally, analysis of variance (ANOVA) was performed to determine the significance of the models. The error % of thrust force and delamination area at hole entry and exit is determined by three validation experiments. Based on the results, the error for delamination area and thrust force was less than 10%. At a feed rate of 0.02 mm/rev, a cutting speed of 1,500 rpm and pecking depth of 2.787 mm, the optimal conditions for minimal thrust force and delamination area were discovered.

DEDICATION

Only
my beloved father, Kumaran Kalrayan
my appreciated mother, Vasantha Subramaniam
my adored sister and brother, Sharmendran and Komala Devi
for giving me moral support, money, cooperation, encouragement and also understandings
Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

CFRP	-	Carbon Fiber Reinforced Plastic.
ACARE	-	Advisory Council for Aeronautics Research Europe.
EMZ	-	Zoom Stereo Microscope.
BRT	-	Bus Rapid Transit.
FEM	-	Finite Element analysis.
ECT	-	Electroconvulsive therapy.
Fd	-	Delamination Factor
Wmax	-	Maximum damage width
W	-	The cut width.
HRA	-	Rockwell Hardness measured on A scale
HAAS	-	Milling Machine Type.
CNC	-	Computer numerically controlled
KISTLER	-	Dynamometer.
OFAT	-	One Factor at a Time

CHAPTER 1

INTRODUCTION

1.1 Background of Study

A composite is defined as two or more different components that are physically connected. Thus, a composite substance has two or more unique constituent elements or phases. Carbon Fibre Reinforced Plastic (CFRP) is one example of a composite. Nowadays, composite materials such as Carbon Fibre Reinforced Plastic (CFRP) are in high demand in industries such as aerospace, aviation, automobile, and sports. This phenomenon is caused by the mechanical features of high specific strength and stiffness and the fact that it is generated in a near-net shape. Because of these qualities, CFRP has effectively been used as a replacement for traditional materials. (Xu & El Mansori, 2016)

Carbon fibre reinforced polymer or carbon fibre reinforced plastic is a fibre reinforced polymer that comprises carbon fibres. It is powerful and lightweight. Although CFRPs are costly to manufacture, they are frequently utilised in applications requiring a high strength-to-weight ratio and stiffness, such as aerospace, automotive and civil engineering, sporting goods, and an expanding variety of other consumer and technical applications.

Many of CFRP's characteristics have contributed to the material's popularity and widespread usage in recent years. In the aircraft sector, CFRP are being employed more and more as major structural materials. Reduced density, high strength, high stiffness, and excellent toughness are all advantages that CFRPs have over other composite materials. They also have minimal friction and good dimensional stability.

As shown in fig 1.1, composite materials account for more than 50% of the structural weight of the Boeing 787. Although composites are manufactured to a near-net shape, assembly requires many holes to be drilled. However, Drilling CFRP laminates is connected with delamination issues, splintering, temperature changes, and geometrical irregularities.(Xu, 2016)

Numerous aspects, including the delamination factors, surface roughness, and thrust force, can substantially impact the dimensional accuracy and precision of composite mechanical parts. An evaluation of the drilling operation could be based on the damage that appears at the hole entry or exit and surface roughness on the hole wall. This is partly due to the delamination phenomena, which causes composite drilling to behave significantly differently from normal metal drilling. During the drilling of laminated composites, delamination is considered significant harm that must be addressed. When there is delamination in the hole, it has a significant impact on the quality of the hole, resulting in unsatisfactory tolerances in the assembly. Aside from increasing surface roughness, delamination also has the additional effect of decreasing fatigue characteristics and decreasing the life of composites. When drilling composites, the effect of push-down delamination at the drill exit can be considered more substantial than the effect of peel-up delamination at the drill entry, which can be considered less significant.

In aerospace applications, the demand for high-grade carbon fibre reinforced plastic (CFRP) components has increased significantly in recent years. Current aviation programmes, such as the European Commission's Clean Sky programme or ACARE's Flightpath 2050, aim to enhance aircraft efficiency to meet future commercial aviation difficulties. Apart from other objectives, this entails a reduction in airplane emissions. By utilizing lightweight materials such as CFRPs, structural mass can be significantly reduced. As a result, less gasoline is spent, and fewer emissions are produced during travel.

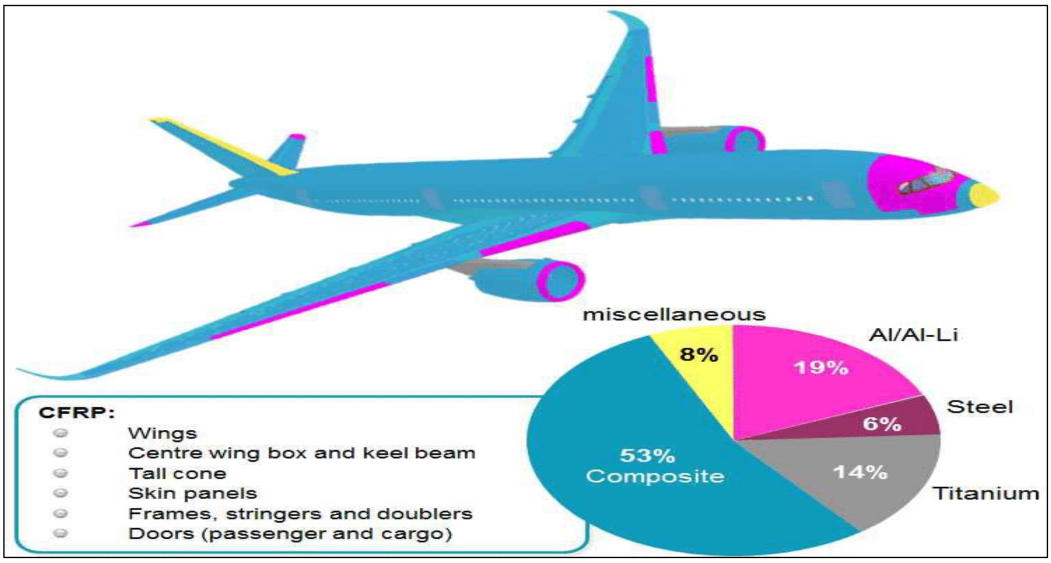

Figure 1.1: Usage of CFRP in Aircraft (Bachmann et al., 2017)

1.2 Problem Statement

Aircraft structures can be built in a fraction of the time by drilling and riveting CFRP and metals together in one operation. As a result of their smaller and lighter weight, composite materials such as CFRP's are used increasingly frequently. CFRP, on the other hand, show a range of damage processes during drilling because of their layered structure and anisotropy. Damage includes delamination, shrinkage of holes, burrs, and thrust force. Composite material's material removal mechanisms are also heavily influenced by angles formed by the cutting speed and the fibre orientation. Moreover, this damage can lead to a negative impact on the production. Other than that, it also can damage the quality and strength of the CFRP.

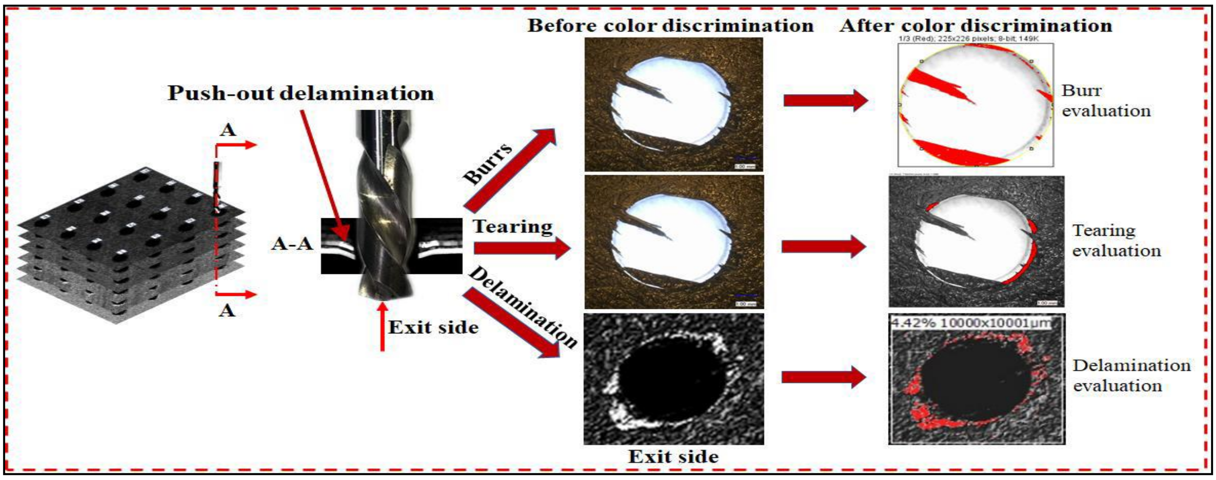

Figure 1.2: Defect after drilling CFRP composite. (Xu et al., 2018)

1.3 Objectives

Based on the problem and difficulties on drilling CFRP composite, the objectives of this project are: -

1. To investigate the influence of machining parameter on entry hole delamination, exit hole delamination and thrust force in drilling CFRP plate.

2. To optimize the drilling parameter for high quality drilled hole.

1.4 Scope

The scope of this project is:

1. This experiment was conducted in low cutting range of (1500 rpm to 3000 rpm) and high cutting range of (3000 rpm to 7000 rpm).

2. Conduct this experiment in dry drilling environment.

3. Diameter and the point angle for the carbide tipped drill is constant.

1.5 Significant of Study

CFRP is often bonded and connected by fusing parts together to form a composite portion. To accomplish this, multiple holes must be drilled, which presents several obstacles due to the material's inhomogeneous composition of fibre and matrix. Drilling CFRP can result in hole damage due to delamination, fibre pull-out, rough surface, edge chipping, uncut fibre, and quick tool wear due to the drill geometrical features. According to the literature, a perfect drill and penetration angle will suit the most for drilling CFRP. Thus, this study seeks to investigate the mechanics of material removal towards the surface quality on the deviation in penetration angle gradually. Moreover, the key important factor such as delamination ratio, surface roughness, force, and tool wear will be evaluated in these studies.

1.6 Organization of Report

Chapter 1

Background information, location of the study, and types of material analysis are all covered in this chapter. Then there are the research objectives and the scope of the study, which is centred on the subject matter of the investigation itself. Also included in this chapter is a discussion of the study's conclusions, which were derived from the analysis.

Chapter 2

This section of the chapter discusses the fundamental theories and the portion of the study devoted to knowledge of the theories. It is based on legal sources and prior studies from online publications, journals, and books. The current equipment is detailed. This section also covers information on the tools used in the manufacturing business. Finally, the proposed alternative is described.

Chapter 3

This chapter discusses the recipe used in this study. It details the procedure followed in this study to collect data from the area under examination. This section will define primary and secondary sources. The process flow chart and the project structure for each of the identified objectives will be detailed.

Chapter 4

Elaborates and discusses the findings obtained from this research. The findings were discussed comprehensively, starting with analysis of variance (ANOVA). After the range of parameter is optimized, Full Factorial method is used to optimize the thrust force and delamination area. Next, the condition for optimization is shown to get the optimum parameter. Finally, the optimum parameter is confirmed by validation test.

Chapter 5

Explained the summary of the outcome from the overall research. The possible recommendations for future work, novelty and the contribution of the knowledge is elaborated in the final section of this chapter.

1.7 Summary

This chapter establishes the foundation for understanding the entire subject of this investigation. This chapter summarises the research and aids the reader in comprehending the idea. The most critical components of this study are the objectives that must be met and the project scopes that must be followed for the study to be effective.

CHAPTER 2

LITERATURE REVIEW

2.1 CFRP Composite

Composites CFRP are a frequently utilized material due to their flexibility to a variety of conditions and the relative ease with which they can be combined with other materials to fulfil specific purposes and display desirable features.

Plastic resins have enabled the development of non-metallic materials that are frequently superior to metals in terms of strength or weight ratio, corrosion resistance, fabrication ease, and cost. Composite structural materials are comprised of a range of different materials and come in a variety of shapes and sizes.

According to (Geier & Pereszlai, 2020), an inhomogeneous and anisotropic material, CFRP is difficult to cut because of its abrasive wear effect, and carbon fibre reinforcements have to be removed from the cutting zone due of their abrasive impact (usually by a vacuum device). CFRP anisotropy may be measured by measuring the fibre cutting angle (θ), a 90-degree angle between the cutting speed vector and the fibre reinforcement vector., as shown in Fig. 2.1.