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Drilling of Aero Composite Material

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ABSTRACT

Composites are two or more material that is combined to form a much stronger structure than either material itself. Drilling process of aero composites material is the most critical procedure in the whole aspect of its manufacturing process. This study is focused on the analysis over the factor of feed rate and speed of the CNC milling machine for drilling through aero composite material. It is also to analyze the factor of drill bit type which Dagger drill bit, Fish Tail drill bit, and Twist drill bit have been chosen. This research is to investigate the interaction of factors values that are most suitable, the best type of drill bit and the application of backup plate to minimize or eliminate the defects on the aero composite panel during drilling process. The aero composite panel was cut into specimen size, 75 mm x 35 mm by using hacksaw to get 24 specimens. Then, a hole was drilled through each specimen with diameter of 5 mm with different orientation of feed rate and speed. The cutting speed and the feed rate for the drilling process is factorial arranged with high and low value. Half quantities of the specimen were drilled with backup plate laid under the specimen. Then, the side wall of the hole is measured by using Portable Surface Roughness Tester to measure the surface roughness. An observation to the condition of the drilled hole area is done with Scanning Electron Microscope (SEM) to compare the difference in backup plate application in machining and to see which drill bit produce best drilling job. Universal Testing Machine (UTM) was used to do flexural test and get the maximum force can be hold by the drilled panel. From the study, it was found that the interaction that produces higher maximum force that can be hold by drilled specimen is chosen to be the best interaction of factors can be use in drilling of aero composite material. The use of back up plate is also managed to reduce the burr and delamination of the panel. From the image analysis also we can see that the Twist drill is the best drill bit to be use.

ABSTRAK

Projek ini memfokuskan kepada analisa ke atas kadar *feed* dan kelajuan mesen CNC untuk proses dril ke atas bahan aero-komposit. Ia juga untuk mengkaji faktor penggunaan jenis-jenis mata dril tertentu seperti *Twist, Dagger* dan *Fish Tail*. Projek ini adalah bertujuan untuk mengkaji nilai faktor, jenis mata alat yang paling sesuai dan penggunaan *backup plate* untuk meminimakan atau menghapuskan kerosakan ke atas bahan kerja semasa proses dril dijalankan. Panel aero-komposit dipotong kepada saiz 75 mm x 35 mm untuk mendapatkan 24 keping bahan kerja. Satu lubang ditebuk pada setiap bahan dengan diameter 5 mm dengan penggunaan orientasi kelajuan dan *feed* yang berbeza. Nilai-nilai kelajuan dan *feed* yang digunakan, disusun dalam bentuk faktorial dengan penggunaan nilai tinggi rendah. Separuh daripada bilangan bahan ditebuk dengan penggunaan *backup plate*. Kemudian dinding lubang yang ditebuk diukur dengan menggunakan *Surface Roughness Tester* menguji kualiti permukaan dinding lubang yang didril. Seterusnya pemerhatian terhadap keadaan lubang kesan drill dilakukan melalui mikroskop pengimbas electron (*SEM*). Selain itu, ujian kelenturan oleh mesen penguji universal (*UTM*) dijalankan untuk menguji kekuatan bahan yang didril. Daripada hasil kajian, didapati bahawa kombinasi faktor pemesenan yang menghasilkan bahan kerja yang dapat menahan nlai beban yang paling tinggi adalah kombinasi faktor pemesenan yang paling sesuai digunakan. Penggunaan *backup plate* juga telah berjaya mengurangkan berlakunya *burr* dan *delamination* pada bahan spesimen. Melalui analisa imej, *Twist drill* merupakan jenis mata dril yang paling baik digunakan.

DEDICATION

To my beloved family and friends

Miswan Sairi

Fatimah Embong

Fatin Najwa

Nurul Nadia

Amirul Asyraf

Ammar Faiz

Aiman Syafiq

Megat Armia

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

CNC	-	Computer Numerical Control
CTRM	-	Composites Technology Research Malaysia
DoE	-	Design of Experiment
FEP	-	Fluorinated ethylene-propylene
GFRD	-	Glass fiber reinforce prepreg
OA	-	Orthogonal Array
PFA	-	Perfluoroalkoxy polymer resin
PTFE	-	Polytetrafluoroethylene
Ra	-	Roughness average
SEM	-	Scanning Electron Microscope
UHMWPE	-	Ultra high-molecular weight polyethylene
UTM	-	Universal Testing Machine

CHAPTER 1
INTRODUCTION

1.1 Background

Composites are two or more material that is combined to form a much stronger structure than either material itself. Matrix and reinforce material retains its unique identity in the composite which not melted together as in a metal alloy. Each material contributes its own structural properties. Advance composites are generally considered to be composite which exhibit higher strength to weight ratios than the composite made of "ordinary" fiberglass and resin. They are more expensive than ordinary composite (U.A. Khashaba, M.A. Seif and M.A. Elhamid, 2006).

Drilling aero composites is the most critical process in the manufacturing of aviation parts. It is usually the final operation during the assembly of the structures in these applications. Poor hole quality accounts for an estimated 60% of all part rejection, and since holes are drilled in finished products, rejection of parts due to poor hole quality leads to loss (H. Hocheng and C.C. Tsao, 2005). The economic impact of this is significant considering the value associated with the part when it reaches the assembly stage. The quality of the drilled holes such as waviness/roughness of its wall surface, axial straightness, and roundness of the hole cross section can cause high stresses on the rivet, which will lead to its failure. Stress

concentration, delamination, and micro cracking associated with machined holes significantly reduce the composite performance.

To reduce the defect of aero composite material during drilling process, it is essential to determine the factors, elements, methods and the drill bit features for the drilling operation. It involves many aspects such as the spindle speed rate, feed rate, drill diameter, specific cutting pressure, the thrust force, torque, drill temperature, tool design parameters and the influence of tool wear.

1.2 Problem Statement

Drilling process of aero composites material is the most critical procedure in the whole aspect of its manufacturing process. Any defects that lead to the rejection of the parts represent an expensive loss. In the aircraft industry, drilling associated delamination accounts for 60% of all part rejections during final assembly of an aircraft. The part must be rejects even for the slightest defect because it can risk the life of countless passengers on the aircraft. The composites performances are reduced due to the bad quality of the drilled holes. The hole machining defects have significantly reduced the strength and fatigue life of carbon/epoxy laminates.

Other than hole crack and burr, interlaminar delamination is also among the serious concerns during drilling process of aero composites material, which could affect the structural integrity, and long term reliability. The main cause of mechanical failure is the micro-damage generated at the inner part of the hole surface, while delamination plays a minor role. Delamination occur both at the entrance and exit planes of the workpiece. The center of the twist drill induces a large thrust force, causing separation of plies at the exit as the interlaminar bonding yields. The

influence of tool wear can increases the thrust force. The effect of processing variables also contributes to drilling damage. The effect of chisel edge on the thrust force is linear. The larger the chisel edge, the larger the thrust and the induced delamination (H. Hocheng and C.C. Tsao, 2005). There are still no resolutions to determine delamination-free and burr-free holes in drilling of aero composites material.

1.3 Objectives

(a) To study the performance of three types of drill bit (twist, dagger and fish tail) in drilling of aero composites material.
(b) To investigate the factors and variables that affecting the quality of the hole.
(c) To study the application of back up plate for drilling aero composites process.
(d) To determine the most suitable value of variables and the best type of drill bit for drilling aero composites material.
(e) To analyze and compare the result of the drilling effect with and without the application of the backup plate.

1.4 Scope

The scope of the study is to evaluate the best type of drill bit for drilling of aero composites material and to determine the most suitable proportional value of variables for drilling process of aero composites material. Last but not least, to differentiate the result of the drilling effect with and without the application of the backup plate. All of the findings are depends on the flexural test, surface roughness measurement and image analysis that been done to the drilled hole of aero composite material.

1.5 Organization

On the first chapter stated about the background of the study and the project that being handle. Then the problems that contribute to the purpose of this project are stated as an overview of the matters that going to be solve. The objectives of this project are also listed down as a guideline to accomplish this personal project. Lastly, the scope and key assumption of this project are stated here to picture the goal of the project.

Chapter two is the literature review of this study and project that consist of introduction to drilling carbon fiber-reinforced composite material, effects of drill bits on drilling of aero composite material, influence of process parameters on cutting force and torque, and backup plate application for drilling process. It reviews about the relevant information to the study.

Chapter three is the methodology that appraises about the methods that been use in this project to accomplish the objectives and the scope of study. It contains the design of experiment, controlled factors, the backup plate application, the machining method, the results analysis and the performance investigations.

Chapter four is the results obtain from the measurement and data analysis that have been done to the drilled aero composite material. All the graphs and tables shows the findings clearly and the finding is elaborated in the sentence form for better understanding.

Chapter five is the discussion that explains about the findings in results that obtain from the drilling of aero composite material analysis. All the findings and

problems are discussed and related to previous studies. Then it will be summarize for clearer understanding.

Chapter six is the conclusion for this study that concludes all the achieved objectives and also stated the recommendation for improvement for further investigations of the same study in future.

CHAPTER 2
LITERATURE REVIEW

2.1 Aero Composites

Composites is two or more material that is combined to form a much stronger structure than either material itself. It consists of matrix and reinforcing material which each material retains its unique identify in the composite where they not melted together as in a metal alloy. Each material contributes its own structural properties.

Advance composites are generally considered to be composite which exhibit higher strength-to-weight ratios than do composite made of "ordinary" fiberglass and resin. They are more expensive than ordinary composite and the properties are usually precisely tailored to achieve specific objective.

Matrix is the non-oriented material (e.g. resin) in which the fibers of a composite are imbedded. It acts as glue that transfers loads from fiber to fiber and holds the fibers together and then gives a part its shape. Matrix types divided to two types which are thermosets and thermoplastic (Anonymous, 2006). Thermosets is the organic type which is the most common matrix type. It undergoes a chemical change

when it cures and cannot be reformed or melted after curing that makes it difficult to be recycled (E.g. polyester, vinyl ester, epoxy, phenolic). Thermoplastic undergoes a physical change from solid to liquid when heated and solidifies upon cooling. It can be reheated and reformed, melted at high temperatures and recyclable (E.g. Plexiglas, polyethylene).

There are many types of reinforcing fibers such as Fiberglass (glass cloth), Carbon Graphite, Aramid, Boron, and Ceramic. The fiber orientation is warp, fill (weft), selvage edge, and bias. The fabric styles are unidirectional, bi-directional or multidirectional, and mats. Hybrids are the different type of fiber orientations such as intraply hybrids, interplay hybrids, and selective placement.

There are many possible combinations of resin system and fiber reinforcement and depending upon the specific application the optimum selection can be made. There are some of the most commonly used fibers, along with the most commonly available forms. Carbon fibers have high end low weight high strength application such as structural reinforcement and aerospace parts. Glass fibers have low cost enforcement for general application and widely used in corrosion resistance. Aramid fibers have high end impact absorption application such as ballistic protection.

Pre-impregnated or "prepreg" are simply fabrics that have the resin system already impregnated into the fabric. There are three stages in the life of a resin system. The A-stage is as mixed and has low viscosity. It is often diluted with solvent and used to impregnate cloth by the prepregger. The B-stage is partially cross-linked and most solvent evaporate out. It is still tacky but not flowing. This is the stage in which prepreg is used to make parts. C-stage is the cross-linked to the point where the resin is insoluble and infusible. Prepreg at this stage cannot be used to make parts due to very poor bonding between plies (Anonymous, 2006). It may or may not be fully cured.