MODELLING EFFECT OF CUTTER GEOMETRICAL FEATURE FOR TRIMMING CFRP COMPOSITE

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

By

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I hereby, declared this report entitled **"MODELLING EFFECT OF CUTTER GEOMETRICAL FEATURE FOR TRIMMING CFRP COMPOSITE"** is the results of my own research except as cited in references.

Signature : ……………………..
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Date : ……………………..

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory committee is as follow:

DR. RAJA IZAMSHAH BIN RAJA ABDULLAH

(Project Supervisor)

ABSTRAK

Polimer Bertetulang Gentian Karbon (CFRP) telah digunakan secara meluas dalam pelbagai industri terutamanya dalam industri aeroangkasa dimana ia mempunyai nisbah sifat yang kuat dan ringan serta mampu untuk menghasilkan struktur besar yang padu. Pada panel CFRP, sebahagian kawasan periferal mempunyai kualiti yang tidak stabil akibat daripada proses penghasilan itu sendiri. Oleh itu, altenatif yang digunakan ialah dengan membina satu bahagian persisian tambahan pada bendakerja itu dan ia perlu dipotong bagi mendapatkan produk dengan menggunakan proses pemangkasan. Semasa proses pemangkasan, kualiti pada permukaan CFRP menjadi rendah kerana sifat ketidakhomogen pada bahan komposit. Ramalan yang tepat mampu memberi impak dalam pembangunan standard dalam pemprosesan CFRP disamping dapat mengoptimumkan parameter yang berkaitan dengan kualiti bahan. Dalam laporan ini, kaedah baru bagi meramal proses pemangkasan komposit telah dijelaskan. Laporan ini juga bertujuan untuk mengkaji kesan mata heliks pemotong pada bahagian kiri dan kanan semasa proses pemangkasan. Metodologi digunakan berdasarkan kepada gabungan Kaedah Unsur Terhingga (FEA). Keputusan dariapada model ramalan telah disahkan oleh ujian pemangkasan yang sebenar. Ia dikaji pada peringkat berbeza diantara sudut alat heliks. Laporan ini dapat membantu dalam memperkayakan pengetahuan dan pemahaman dalam kesan pemangkasan oleh ciri alat heliks kiri dan kanan. Ciri- ciri heliks pada mata pemotong berfungsi sebagai pembuang bahan dan ciri heliks pada bahagian kanan bertindak sebagai bahagian utama dalam proses pemotongan dan bahagian kiri bertindak sebagai ciri sekunder yang membantu membuang dan meratakan cebisan daripada bendakerja. Dengan pembentukan formasi cip, kajian ini juga menggambarkan pendekatan yang berbeza untuk mengkaji keputusan kekasaran permukaan disamping model ini telah terbukti dapat mengurangkan masa pengkomputeran dengan membina model berasaskan elemen shell pada tiga dimensi.

ABSTRACT

Carbon Fibre Reinforced Polymer (CFRP) has found widely used for multi- purpose in many of industries, especially in aerospace industries due to the great in strength to weight ratio as well as the ability to create large integrated structure. In a CFRP panel or the like, a peripheral portion becomes a region having an unstable quality because of the production process. In practice the part is ideally been fabricated oversize and will be trimmed using cutter to obtains the specific size. Due to the inhomogeneous nature of CFRP composite, the trimming process can be challenging. To secured a good surface finish CFRP part, understanding the phenomenon during the material removal is crucial and should be methodically analysed. Accurate prediction of the trimming result will allow development of standard in processing CFRP and able to optimize the parameter that controls the risk of consequences. In this report, a new methodology for the prediction of composite trimming is presented. This report also aims to study the effects left and right tool helical features on the CFRP trimming. The prediction methodology is based on a combination of finite element analysis (FEA) method. It consists the model of the prediction, which is used to take into account the tool- work geometries on material removal during the trimming process. The prediction values have been validated by trimming tests on a CFRP panel with different type of the tool helix angle. This report may assist in enriching the knowledge and understanding of effects of left and right tool helical features. The left helical features serve as a secondary material remover whereby it removes excess material from right helical features as a primary material remover. This research also illustrated the differences of approach that used to indicate the results on surface roughness by using chips formations. In the sense of reducing computing time, this model has proven to employ shell elements to model the three dimensional parts.

DEDICATION

This report dedicated to my beloved parents and siblings. Thanks for always being there for me. Without their love and support this report would not have been made possible.

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In the name of Allah, the Most Merciful and the Most Beneficent. It is with the deepest senses gratitude of the almighty that gives strength and ability to complete my PSM.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

2D	-	Two Dimensional
3D	-	Three Dimensional
CFRP	-	Carbon Fibre Reinforced Polymer
CBN	-	Cubic boron nitride
CPU	-	Central processing unit
FEA	-	Finite Element Analysis
IGES	-	Initial Graphics Exchange Specification
Knn	-	Stiffness values for a Traction (Stress) normal direction 3
Ktt	-	Stiffness values for a Traction (Stress) tangential directions 1
Kss	-	Stiffness values for a Traction (Stress) tangential directions 2
L8 R35	-	Left helix angle 8° with right helix angle 35° tool
L7 R40	-	Left helix angle 7° with right helix angle 40° tool
L10 R47	-	Left helix angle 10° with right helix angle 47° tool
R3D4	-	4-node 3-D rigid triangular facet
RPM	-	Revolutions per minute
S4R	-	4- node doubly curved thin or thick shell
STEP	-	Standard for the Exchange of Product Model *Data*

Ti	-	Titanium
$\bar{\sigma}$	-	Plastic flow stress
$\bar{\varepsilon}$	-	Plastic strain
$\dot{\bar{\varepsilon}}$	-	Equivalent plastic strain rate
n	-	Strain hardening exponent
$p/\bar{\sigma}$	-	Ratio of the pressure
τ	-	Surface traction
μ	-	Friction coefficient
p	-	Contact pressure

CHAPTER 1

INTRODUCTION

This section provides the background of the research that focuses on the modelling of cutter geometrical features on Carbon Fibre Reinforced Polymer (CFRP) trimming. The background of the research included the nature of the composite and particularly CFRP. The effect of tool geometry influenced the quality of material and the basic of the Finite Element Analysis (FEA) were also briefly introduced. In addition, this chapter also discusses the challenges in CFRP trimming followed by the research objectives and scope.

1.1 Background

Hybrid material which also known as composite is widely used for multi- purpose in many of industries, especially in aerospace industries because this material offer high strength to weight ratio as well as the ability to create large integrated structure. For instance, the Boeing 787 Dreamliner (Figure 1.1) consists of 50 % composite material by weight, with much of that being carbon fibre laminates or sandwiches. CFRP consist of the carbon fibres, which are effective in reducing the weight of structures and their demand has been increasing in airplanes, automobiles etc. (Oka et al. 2009). The tensile strength of this material is similar to the high- strength steel and the elastic modulus of CFRP is better than titanium (Ti). Therefore, these properties made this material to have superior material characteristics (Hagino and Innoue, 2013).

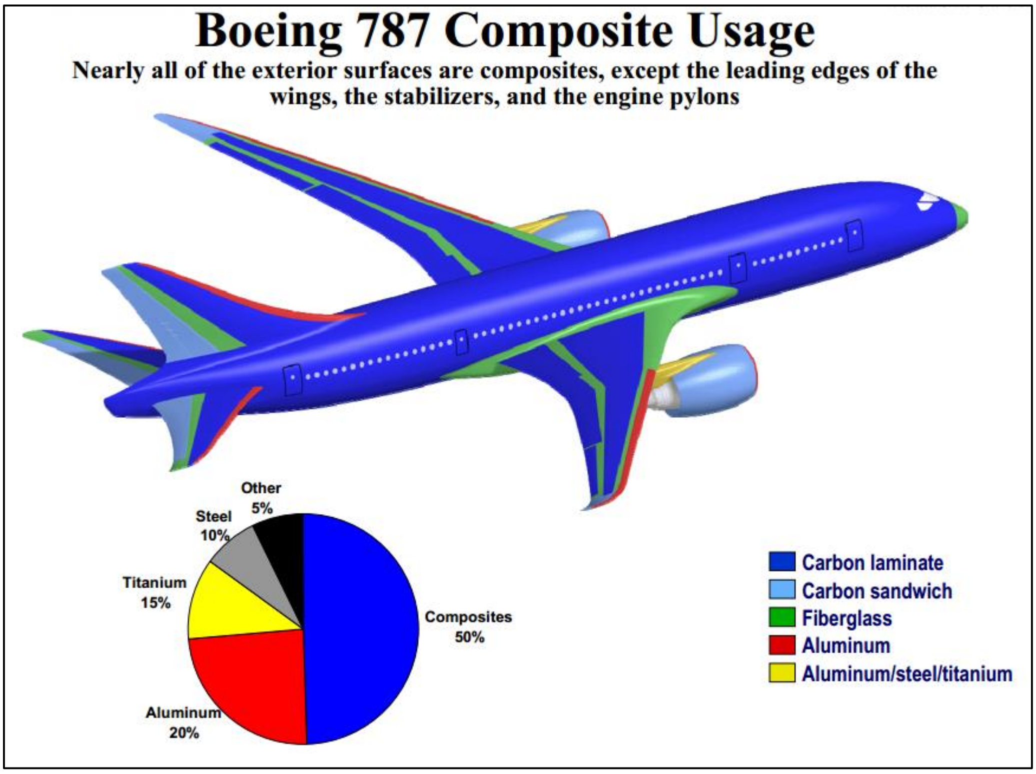

Figure 1.1: The material used in Boeing 787 Dreamliner
(Source: <http://webfiles.wichita.edu/cedbr/WIRED_comp_ov_5_14_08.pdf>09/10/13)

The mechanical strength of this material is affected by two major factors, which are the amount of distributions state of carbon and the bond of the binding material. Based on Oka et al. (2009), in a CFRP panel or the like, a peripheral portion becomes a region having an unstable quality because of the production process. Therefore, a method is employed in which it is required to fabricate an extra peripheral portion in advance, and after the resin is cured, the extra peripheral portion is cut off to get the product.

The trimming by using an end - mill cutter provides several advantages in which it does not require the large- scale equipment and the existing processing machine still can be used. Furthermore, the extra peripheral portion able to be removes without preparing pilot holes. (Oka et al. 2009).

According to Kalla et al. (2010), CFRP is difficult to machine because during the machining, the unstable surface finish occurred by strong anisotropic effect of carbon fibre. The primary machining processes goal is to achieve the most efficient separation of chips from the workpiece. Therefore, the selection of the right cutter geometry is critical.

In consequence to the cost and time- consuming to conduct an experiment according to the design of experiment, prediction models is the best solution as it offer lots of advantages which allows a prevalent tool to analyse arbitrary geometries and loading conditions. Between the presences of numerical methods, FEA has been comprehensively used with success. Nevertheless, this analysis needs a large set in generation data in order to obtain authentic and accurate results.

The advantages of the prediction model in the machining will lead to optimize the performances of the cutting tool besides enhancing the quality of the workpieces. By developing the prediction model, the circumstances that occurred by cutting process able to discover and be able to analyse the phenomenon. Therefore, any of the factors that contributed to the performance and quality issues can be control.

1.2 Problem Statement

Trimming of CFRP is a common activity in the manufacturing of aircraft, marine and automotive application. Since a CFRP is a material for which burrs easily occur, even when the abrasion of the cutting edge is considered to be at a level that does not cause a problem in metal machining, burrs occur in CFRP machining, and the cutting tool is determined to have reached the end of its life at that moment. Therefore, even in an end mill coated with a high-hardness coating, the end mill life is short in CFRP machining (Oka et al. 2009).

1.2.1 Challenge in CFRP Machining

There are many consequences that occurred during the machining of CFRP as shown in Figure 1.2. Common defects that may occur during machining of these materials are: rapid tool wear, fibre pull-out, splintering surface burning and smearing, pitting and delamination (Kalla et al. 2010). This entire problem is caused by the inhomogeneous nature of composite materials. Furthermore, CFRPs used for fuselages, wings and other parts of airplanes that are large in size in many cases, and fixing of such large workpieces easily becomes unstable because fixing points are limited during machining.

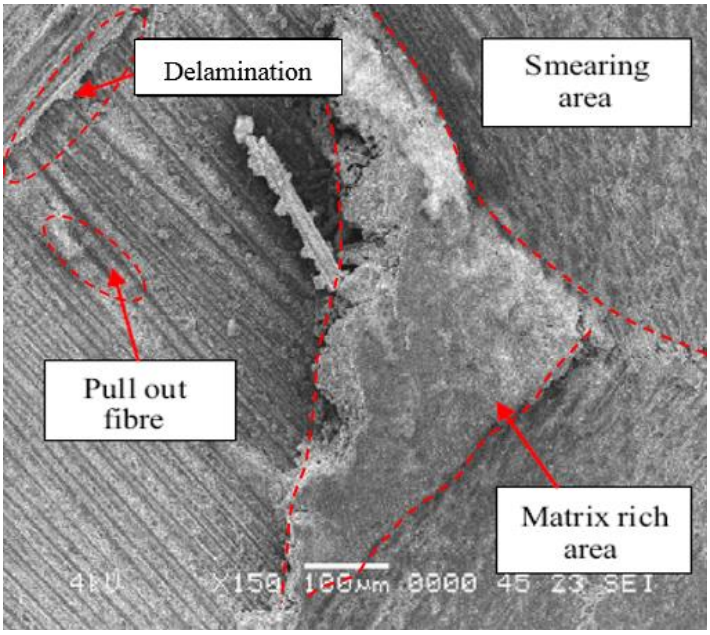

Figure 1.2: Defects on CFRP machined surface (Nor Khairusshima et al. 2013)

Therefore, it would be great if there is an alternative method to predict any complication in CFRP machining. Accurate prediction of the machining result will allow development of standard in processing CFRP and also able to optimize the parameter that controls the risk of consequences that can be intimidate of the material quality as well as the cutting tool performance.

To determine the relationship between CFRP and tool geometry, it is necessary to conduct an experiment, but there are lots constraints to conduct the actual experiment in terms of time and cost. CFRP is more costly due to their processing from primary material to hybrid material and by conducting the actual experiment; it would require lots quantity of CFRP as specimens and cutting tool as performance parameter.

Thus, the use of simulation in conducting the experiment can bring many benefits that will save both time and money, but there are no any appropriate method to simulate as well as studies on trimming of the composite structure not to mention CFRP.

1.2.2 Challenge in FEA modelling

Basically, the FEA modelling has become a daily engineering tool. But without proper fundamental knowledge and guidance will lead to poor experimental data correlate with FEA results. There are also have misconceptions about the solid structures represent best results. The challenge in build- up solid model more difficult in meshing because solid models often produces poor meshes with many degenerated elements. Besides that, automatically generated solid meshes need a larger number of elements to indicate the good model of the real stress distribution.

The other challenges in FEA modelling is the time trap, it occurred when the modelling process takes too long time in computing due the limitation of the computer hardware and it would cost a large investment in time. (Andruet et al. 2001). In reducing the cost of analysis, computational time is one of the important factors that should be reduce to allow running a relatively complex model along with modelling uncertainties regarding the boundary and loading conditions.

Modelling structures by using composite materials poses distinctive challenges, especially due to the need for concurrent design of both material and structure. Mostly, the difficulties in design and analysis of composite structures is about the anisotropic nature of the materials and the processing techniques used. The requirement in developing finite element analysis with composite materials are necessary to account for both of these aspects. Although, the widely of commercial FEA codes dominate the anisotropy effectively the application of the processing technique.

Therefore, it would be great if there are have solution in develop the finite element analysis model with minimum of computing time in the area of machining model and composite materials.

1.3 Research Objectives

The objectives of this project are:-

a) To develop a Finite Element Analysis (FEA) model for Carbon Fibre Reinforced Polymer (CFRP) trimming
b) To validate the Finite Element Analysis (FEA) model through the actual experiment.

1.4 Scope and Limitation

The scopes of this project are:-

a) The FEA modelling of CFRP trimming focus on cutter geometrical features
b) Model of cutter assigns as un- deformable part
c) Apply the CFRP properties in Finite Element Analysis modelling
d) Experimental result focus on behaviour of machined surface and roughness.

1.5 Significant of the research

In 2020, two major industrial applications that are wind energy and automotive will account for 46% of the world's total demand for carbon fibre. The forecasts about these phenomena clarify that the global demand for carbon fibre will grow from 37 kilo tonnes in 2011 to 140 kilo tonnes by 2020 as shown in Figure 1.3.

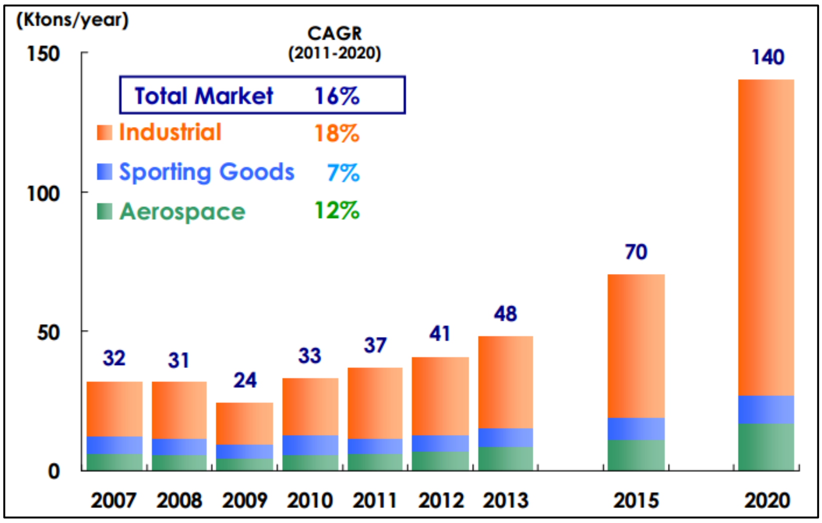

Figure 1.3: The global demand of CFRP start from 2007 until 2020
(Source: <http://www.toray.com/ir/pdf/lib/lib_a136.pdf> 09/10/13)

In addition, in terms of producing a CFRP panel, there are sections that called peripheral becomes an area that having unstable quality causes by the production process. Therefore, the current method to eliminate this problem is to produce the parts with an extra peripheral portion during the fabrication process. Then, after the resin cured, the extra peripheral portion is removed (cut off) to obtain a product. Therefore, this case was lead to requirement in trimming process of CFRP nowadays. The accurate prediction of the trimming results will increase the quality of the CFRP composite besides capable to optimize the parameter that controls the risk of consequences that can be intimidated of the material quality.

1.6 Structure of Dissertation

This report consists of five chapters which is covered on Projek Sarjana Muda I (PSM I) and Projek Sarjana Muda II (PSM II). The chapters of the reports are organised as follows:

The first chapter is an outline of the overview project, problem statement, objectives, scope of work and the structure of the report.