A STUDY ON THE EFFECT OF CUTTING TEMPERATURE DURING MILLING OPERATION OF CFRP MATERIAL UTILIZING VARIOUS TOOL GEOMETRICAL DESIGN; ROUTER/BURR TOOL

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

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NUR AYUNI SHAHIRAH BINTI ABDUL RAHIM

A thesis submitted
in fulfilment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

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2023

DECLARATION

I declare that this Choose an item. entitled "A Study On The Effect Of Cutting Temperature During Milling Operation Of CFRP Material Utilizing Various Tool Geometrical Design; router/burr tool"is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : NUR AYUNI SHAHIRAH BINTI ABDUL RAHIM

Date : 21/01/2023

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature :

Supervisor Name : TS. DR. SYAHRUL AZWAN BIN SUNDI

Date : 22/02/2023

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DEDICATION

I dedicated this thesis to my beloved parents and lecturers who have always been my nearest and educated me to reach this level.

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ABSTRACT

The measurement of cutting temperature is important when dealing with CFRP. Temperature is a key factor that affects the quality of carbon fibre reinforced polymer (CFRP) cutting. Degradation of resin will occur within the machined surface or surface layer with the temperature rise. In this research, the cutting temperature during trimming of CFRP material using cutting mechanism router and burr with respect to the cutting force as well as surface integrity were evaluated as there are various tool geometries which 3 different types which is only differentiated by number of teeth/flutes & helix angle. Consistent cutting/machining parameters (cutting speed & feed rate) was applied for all selected tool geometries using CNC Router Milling Machine. Mitutoyo Surf-Test was used to evaluate the surface quality, Ra (average roughness). Cutting force of Kistler Dynamometer adopted to obtain the cutting forces during trimming. To measure cutting temperature, thermal camera fluke ti400 used to extract the temperature data during the trimming process to be analysed. Ultimately, the effect of tool geometries and surface finish towards cutting temperature is investigated at the end of the project milestone using Nikon mm 800 optical microscope.

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ABSTRAK

Pengukuran suhu pemotongan adalah penting apabila berurusan dengan CFRP. Suhu adalah faktor utama yang mempengaruhi kualiti pemotongan polimer bertetulang gentian karbon (CFRP). Degradasi resin akan berlaku dalam permukaan mesin atau lapisan permukaan dengan kenaikan suhu. Dalam penyelidikan ini, suhu pemotongan semasa pemangkasan bahan CFRP menggunakan burr mekanisme pemotongan dan penghala berkenaan dengan daya pemotongan serta integriti permukaan dinilai oleh kerana terdapat pelbagai geometri alat iaitu 3 jenis berbeza yang hanya dibezakan dengan bilangan gigi/seruling & sudut heliks. Parameter pemotongan/pemesinan yang konsisten (kelajuan pemotongan & kadar suapan) telah digunakan untuk semua geometri alat yang dipilih. Mitutoyo Surf-Test digunakan untuk menilai kualiti permukaan, Ra (kekasaran purata). Daya pemotongan Dinamometer Kistler pula digunakan untuk mendapatkan daya pemotongan semasa pemangkasan. Untuk mengukur suhu pemotongan, kamera terma fluke ti400 mengekstrak data suhu semasa proses pemangkasan untuk dianalisis selanjutnya. Akhirnya, kesan geometri alat dan permukaan akhir terhadap suhu pemotongan disiasat pada penghujung pencapaian projek menggunakan Nikon mm 800 optical microscope.

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LIST OF ABBREVIATIONS AND SYMBOLS

N	-	Newton
µm	-	Micrometer
mm	-	milimeter
CFRP	-	Carbon Fiber Rienforcement Plastic

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CHAPTER 1

INTRODUCTION

1.1 Background

Carbon fiber reinforced polymer (CFRP) composites are widely applied in a variety of industries, including aircraft, automobile, sports, and energy due to their high strength-to-weight ratio, excellent damping ability, and low density, carbon fiber reinforced polymer (CFRP) composites.(Wang, Sun, Zhang, et al., 2016).

CFRP applications require fewer machining processes than metal materials due to near net form manufacturing. Drilling and milling, however, are still required to give the CFRP parts their final shape and ensure assembly precision. CFRP is difficult to process because it is nonhomogeneous, anisotropic, and fiber reinforced. Cutting can have several unwanted effects that reduce fatigue strength, lowering composite laminates long-term performance. Cutting flaws were found to be primarily driven by a variety of factors, including machining settings, cutting tool, and fiber orientation. Cutting quality is impacted by cutting force and cutting temperature as a result of changes in other parameters.

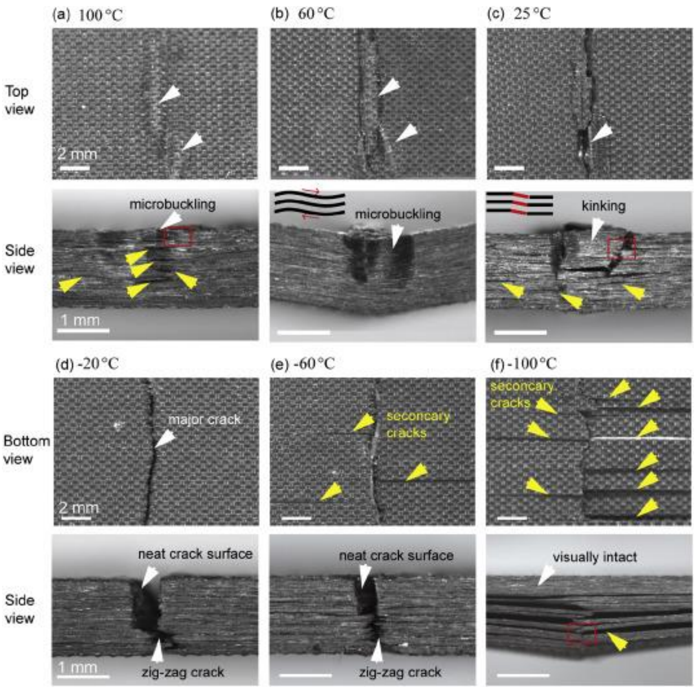

Figure 1.1 Example of CFRP defect. (Jia, Li, et al., 2018).

Cutting force in CFRP cutting has been studied using experimental, analytical, and numerical modelling techniques in the literature. the cutting quality is influenced by the cutting force and cutting temperature. The relationship between milling temperatures and fiber orientation is studied while using various tool geometrical design.(Wang, Sun, Zhang, et al., 2016).

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CNC Router Milling Machine and the router and burr tool was used in this research. In CNC Router machine, the control unit contains a dedicated computer which uses the data provided in the part program to control the machine tool. The complete program to produce a component is input and stored within the memory computer and calculating of work or tool movements.(Wang, Sun, Zhang, et al., 2016).

1.2 Problem Statement

Efficient manufacturing is an important issue due to large industry as automotive and aerospace. The problem in milling operation is the effect of the temperature will influence the quality of the cutting surface of the product especially on CFRP material. There are various geometries available in the market which cater the needs of industries. However, hardly determine which one is the best among all with respect to the two main quality issues namely trimmed surface finish and the tool wear. Therefore, this study initiated to investigate the effect of cutting temperature during trimming CFRP material using various types of tool geometries of router/burr tool type on surface finish and tool wear. It important to maintain the high quality of the tools and surface condition of the product to maintain the accuracy and surface finish.

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1.3 Research Objective

The main aim of this research is to estimate the effect of cutting temperature during milling operation of CFRP material utilizing various tool geometrical design which is router and burr tool. Specifically, the objectives are as follows:

a) To investigate the effect of temperature in milling operation using various router/burr tool geometries.

b) To suggest the most appropriate router/burr tool geometries and cutting condition during milling process of CFRP material with respect to the surface quality & tool wear.

1.4 Scope of Research

The scope of this research are as follows:

- Used Rexcon scanner to scan tool geometry
- CNC Router Milling Machine used for trimming Up-Milling and Down-Milling operation
- Carbon Fiber Reinforcement Plastic (CFRP) material was used in trimming operation
- Used 3 types of various router/burr tool geometries with different geometry
- Dynamometer was placed on CNC Router Milling machine while holding CFRP
- Placed Thermal camera Fluke ti400 Infront experimental setup at CNC Router Milling machine

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- Used SJ-410 for Measuring surface roughness of CFRP
- Used Nikon mm 800 optical microscope to view surface finish and tool wear

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Composite materials are used in a wide range of industrial components and structures, including aerospace, autos, and medical equipment, where high material performance is frequently required. Carbon fiber-reinforced plastics (CFRPs) are a type of composite material that is mostly formed of carbon, and its use is growing. CFRPs are made up of a carbon fiber matrix and epoxy, which has good mechanical and chemical properties. They have the benefit of being able to modify the stiffness and strength of each fiber based on its directivity, number of plies, and physical qualities.(Wang, Sun, Zhang, et al., 2016).

In machining CFRP, cutting temperature has been identified as a major element determining surface integrity and tool life. Because CFRP has a low thermal conductivity, the temperature in the tool-chip contact cannot be properly carried away by small fragment chips, and the workpiece and tool must dissipate a large quantity of heat. If the cutting temperature exceeds the matrix resin's glass transition temperature, the resin will degrade within the machined surface, resultant in thermal damage. Overheating causes a poor surface quality, which reduces fatigue strength and, as a result, degrades the long-term performance of the machined CFRP item. It is frequently required to manage the temperature by adjusting process parameters in order to reduce the overheating problem.(Jia, Fu, et al., 2018).

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2.2 Machinability

Manufacturers attempt to laminate CFRP components in a single operation (molding and hardening), but they frequently need additional processing before they can be utilized or assembled. This is true for the automobile, wind turbine, military, sports, and aerospace industries as well as the aero-space industry. The removal of material build-up from the laminating tool's dividing plane, the removal of surplus material from the tool's flange, the smoothing of the laminated composites' mating surfaces, and the creation of holes for component assembly are a few examples. These post-manufacturing requirements are often satisfied by a variety of machining methods, such as standard drilling, helical milling, tilted helical milling, wobble milling, side milling, or edge trimming.(Geier, 2020).

Machinability refers to how easily a substance may be cut or molded while maintaining a good surface polish. Cutting a material with superior machinability needs less power, results in a smooth surface finish, and reduces tooling wear. A material with poor machinability, on the other hand, necessitates more power to cut, produces a poor surface quality, and wears out the cutting tool. As a result, machinability-challenged materials are more expensive to work with.

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It needs great effort to measure and estimate the temperatures experienced in machining due to characteristics of the operation such as high speeds, number of parameters, size of the heat generation zone etc. Cutting temperature process modelling aids in determining the impacts of cutting parameters and selecting the best ones to create more efficient output. Measurement of cutting temperature, on the other hand, can give important data for verifying suggested models and can also be utilized for online monitoring.(Karaguzel et al., 2016).

Modeling tool wear, chip formation mechanisms, and micro- and macro-geometric mistakes brought on by machining frequently necessitate the investigation of cutting forces. The machinability characteristics of quasi-homogeneous materials are less directional because their mechanical and thermodynamic properties are quasi-isotropic. The machinability of fiber-reinforced materials is thus substantially direction-dependent. However, this is not true for a fiber reinforced composite material. The impact of the fiber orientation angle (the angle between the fibers' direction and the feed rate vector) is discussed in this work. The relationship between cutting force and fiber orientation angle has already been covered in some important works. In the case of up and down milling, there are still a lot of gaps in our understanding of cutting force optimization in UD-CFRP, (Geier, 2020).

2.3 CNC Router Milling Machining

CNC Router milling machining is used to manufacture a wide range of components, and the costs of tooling have continued to decrease. In most cases carbon fiber is machined with a router or milling machine. Large production runs with simple designs are better served by alternative technologies, while CNC machining may meet a wide range of manufacturing requirements. CNC milling is an excellent option for prototyping and short-run manufacturing of complicated parts, as well as the creation of one-of-a-kind precision components. Milling is the one of most common cutting operations in industry. Because the milling process is interrupted, greater speeds may be used, increasing productivity. Cutting temperature is one of the most important parameters to consider while optimizing a process. Cutting temperature analysis is more challenging in milling than in turning owing to experimental challenges and transitory features. In this paper, a novel experimental approach for measuring face milling temperatures is described, which is then utilized to validate the

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analytical model created. The model predictions and dry cutting trials at various cutting speeds show a high level of agreement.(Kong et al., 2021).

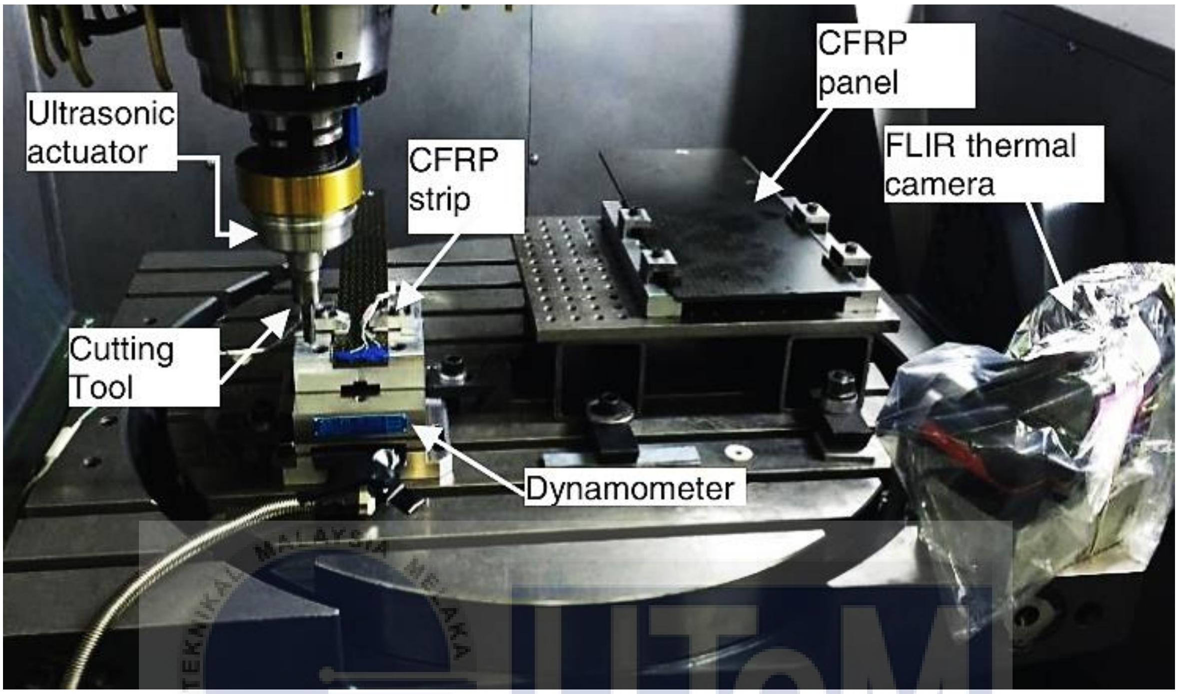

Figure 2.1 Experimental Set-Up for finishing experiment of CFRP.(Halim et al., 2017).

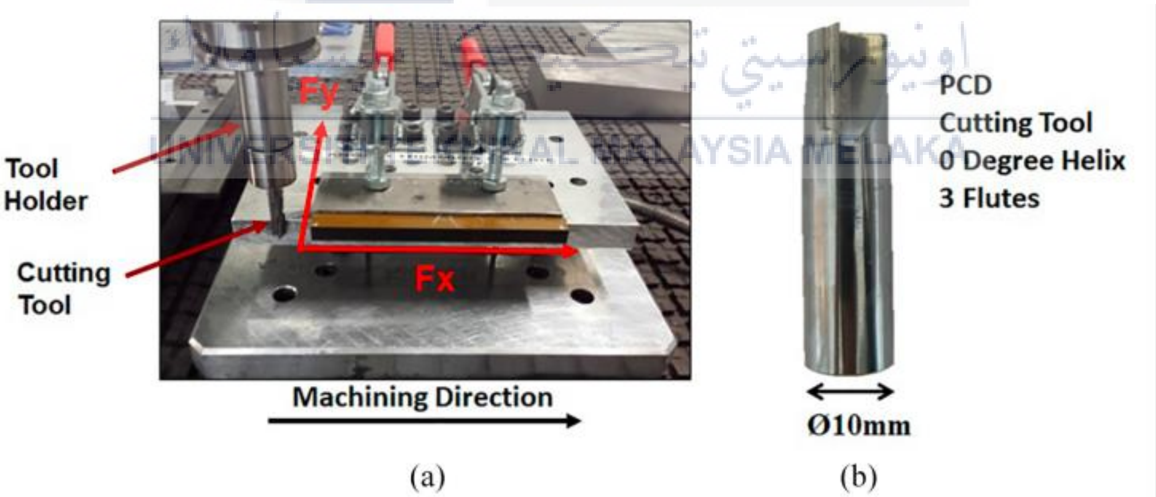

Figure 2.2 Test set-up: (a) Feed force (Fx) and thrust force (Fy) and (b) PCD Cutting tool.(Duboust et al., 2021)

As illustrated in Fig. 2.1, the multi-directional CFRP workpiece was clamped in the jaw vice. Because of its high hardness and wear resistance, the polycrystalline diamond (PCD) end milling router in Fig.2.2 (b) was used. With two PCD tips brazed on the carbide