OPTIMUM TRAJECTORY PATH OF ROBOTIC MANIPULATORFOR TRIMMING PROCESS OF CARBON FIBRE REINFORCEDPOLYMER (CFRP) BASED PRODUCT

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in partial fulfilment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "OPTIMUM TRAJECTORY PATH OF ROBOTIC MANIPULATOR FOR TRIMMING PROCESS OF CARBON FIBRE REINFORCED POLYMER (CFRP) BASED PRODUCT" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date : 4th of July 2021

APPROVAL

I hereby declare that I have checked this report entitled "OPTIMUM TRAJECTORY PATH OF ROBOTIC MANIPULATOR FOR TRIMMING PROCESS OF CARBON FIBRE REINFORCED POLYMER (CFRP) BASED PRODUCT" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degreeof Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : Mohd Khairi bin Mohamed Nor

Date : 5th July 2021

DEDICATIONS

To my beloved family

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ABSTRACT

The focus is to automate the trimming process of Carbon Fibre Reinforced Polymer (CFRP) based product. Trimming is a process of cutting off unwanted parts. It improves the composite in terms of appearance and surface finish for installation of the product. Until now, the trimming process of this product is done manually by workers. This report focused on investigating the optimum trajectory path for the robotic manipulator to accomplish the trimming task. In order to imitate the real task, a CFRP wing part model is developed in Autodesk Fusion 360 software for simulation purposes. The path will then extracted based on the three-dimension model. The problem in this project is how to obtain the optimum trajectory path for the robotic manipulator to perform the trimming task. Based on the problem statements mentioned above, there are three objectives that need to be achieved which are; to identify the trajectory path for the robotic manipulator end effector, design a controller for the robotic manipulator to follow the desired path, and evaluate the controller performance based on standard specifications. Six-degrees of freedom UR10 robotic arm is appropriately selected for the trajectory simulation. The proposed idea to accomplish the objectives of this project are by first creating the path based on the shape of the 3-Dimension model as waypoints. By using Coppeliasim robotic simulator, the kinematics of the robotic manipulator will be monitored to obtain the optimum trajectory path to ensure the efficiency of the trimming task simulation. For the analysis, there will be paths with different number of waypoints that assigned as a group of targets in order to observe the efficiency of the trajectory method.

ABSTRAK

Fokus projek ini adalah untuk mengautomasikan proses pemangkasan produk berasaskan Carbon Fiber Reinforced Polymer (CFRP). Pemangkasan adalah proses memotong bahagian yang tidak diingini. Ia meningkatkan komposit dari segi penampilan dan kemasan permukaan untuk pemasangan produk. Sehingga kini, proses pemangkasan produk ini dilakukan secara manual oleh pekerja. Laporan ini memfokuskan pada penyelidikan jalan lintasan optimum bagi manipulator robot untuk menyelesaikan tugas pemangkasan. Untuk meniru tugas sebenar, model bahagian sayap CFRP dikembangkan dalam perisian Autodesk Fusion 360 untuk tujuan simulasi. Laluan kemudian akan dibuat berdasarkan model tiga dimensi. Masalah dalam projek ini adalah bagaimana mendapatkan jalan lintasan optimum agar manipulator robot melakukan tugas pemangkasan. Berdasarkan pernyataan masalah yang disebutkan di atas, terdapat tiga objektif yang perlu dicapai iaitu; untuk mengenal pasti lintasan lintasan untuk pengesan akhir manipulator robot, merancang pengawal untuk manipulator robot untuk mengikuti jalan yang diingini, dan menilai prestasi pengawal berdasarkan spesifikasi standard. Enam darjah kebebasan lengan robot UR10 dipilih dengan tepat untuk simulasi lintasan. Idea yang dicadangkan untuk mencapai objektif projek ini adalah dengan terlebih dahulu membuat jalan berdasarkan bentuk model 3- Dimensi sebagai titik jalan. Dengan menggunakan simulator robot Coppeliasim, kinematik manipulator robot akan dipantau untuk mendapatkan jalan lintasan optimum untuk memastikan kecekapan simulasi tugas pemangkasan. Untuk analisis, akan ada jalan dengan jumlah titik jalan yang berlainan yang ditetapkan sebagai sekumpulan sasaran untuk memerhatikan kecekapan kaedah lintasan.

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LIST OF SYMBOLS AND ABBREVIATIONS

FYP	-	Final Year Project
CFRP	-	Carbon Fibre Reinforced Polymer
OSHA	-	Occupational, Safety and Health Association
UR10	-	Universal Robot 10
PID	-	Proportional Integrated Derivatives
LSPB	-	Linear Segment with Parabolic Blend
R&D	-	Research and Development
DH	-	Denavit-Hartenberg
3D	-	Three Dimensional
DOF	-	Degree of Freedom
TCP	-	Tool Centre Path
OMPL	-	Operational Method for Production and Logistic
IK	-	Inverse Kinematics
FK	-	Forward Kinematics

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CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

The use of a robot manipulator in assisting task can be convenient ina lot of ways. This is due to the fact that robot manipulator helps lowering energy consumptions, increase production rate as well as the accuracy in the production line [26]. These attributes are the important elements in why we need to shift from manpower to robotic manipulator-based automation especially regarding those tiring repetitive task.

However, to substitute manpower with robotic manipulator, there are several things that are required to ensure that the manipulator could perform an excellent task compared to human. Things that human could easily do like coordination between vision and movement as well as cognitive decision on avoiding obstacles and following trajectory path are the biggest challenges that a robot manipulator need to face. Therefore, a suitable trajectory planning need to be prepared in order for the robot manipulator to work according to the desired task.

In this project, we will discuss on which trajectory planning that easier for us to use and configure as well as the compatible controller for the robotmanipulator to operate in order to complete the trimming task of carbon fiber reinforced polymer (CFRP) based product. The overall trimming task simulated andthe end result will be analyzed based on the standard specification to obtain the desired quality similar to the manpower output. We will analyze the efficiency of the trimming process by conducting experiment with three different kinds oftrajectory paths with different number of waypoints.

1.2 Problem Statement

In this project, the problem and difficulties faced are regarding the previous method of trimming the Carbon Fiber Reinforced Polymer (CFRP) basedproduct. Among the reason stated is that manual method is believed to be the maincauses for the end product appeared to be in low quality. The finishing is not sharpand clean and usually look brushy and the cutting result is slightly inaccurate. Theseproblems will also lead to other types of problem that surely affecting the production of the CFRP [1].

The manual method of trimming the CFRP product also causes severe damage to the human health. According to the Occupational, Safety and Health Administration (OSHA) in 2009, they stated that the mechanical discomfort and abrasion close to those of glass fibers are the major health risks of carbon fiber handling. Carbon fibers are easily broken by stretching (less than 2 percent elongation); during cutting, machining or mechanical finishing, the fibers can easily become fine dust and can then be released into the ambient environment. If unchecked, these micro fibers have the ability to stick into human skin or irritation-causing mucous membranes [2].

In this project, the problem on investigating the path planning of robot manipulator for trimming process is in generating trajectory based on position(θ), velocity (θ) and acceleration (θ) for 6 DOF robot for the uniform trimming procedure on the CFRP based product. This is because, the velocity of the robot should be constant throughout the path planning. Besides, the orientation of the tool center path (TCP) should be aligned with the edge of the product.

1.3 Objectives

The objectives of this project are:

i. To identify the trajectory path for the robotic manipulator end effector.

ii. To evaluate the trajectory path performances based on desired specifications.

1.4 Scope and Limitations

Scope and limitations in this study include:

i. Use Coppeliasim software for simulation purposes.

ii. Use a six Degree of Freedom (DOF) robotic manipulator for the trimming process.

iii. The type of trimming Tool Center Path (TCP) as the robotic manipulator end effector is not considered in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews studies that have some similarity to the other researchers' experiments. There is a comparison between the type of trajectory generation that will be applied and some of the mathematical modeling by each article that has been found.

2.2 Previous Method of Trimming CFRP Based Product

Conventional material removal processes such as turning, sawing, grinding, and milling are often used to machine-finish fully cured carbon fibre reinforced polymer (CFRP) parts. Machining loss is possible in such systems, and sufficient steps should be taken so that this damage is reduced. Tool wear and the related cutting tool forces crushing the machined surface include causes of machining injury. Excessive instrument forces, mainly the force component normal to the stacking direction, are caused by surface and inter-ply delamination, and heat damage to the matrix results from heat build-up [3].

Because CFRP machining happens by fracturing, and very little plastic deformation is involved, in order to neatly shave the material, an acceptabledegree of edge sharpness is needed. In the milling setup, routing of CFRP compositematerial with burr tools was done and machining efficiency was examined in termsof surface roughness and style and depth delamination. With an increase in feed rate and a decrease in spindle speed, surface roughness improved in the longitudinaldirection, leading to an increase in effective chip thickness. With an increase in feedrate and a reduction in cutting speed, the average delamination depth increased, leading to an increase in effective chip thickness. [3,4].

Figure 2.1 Outcomes from conventional method of trimming CFRP

Figure 2.1 shows one of the disadvantages caused by conventional method that need to overcome by using robotic technologies. Figure 2.2 shows delamination that occur during drilling process of CFRP based product.

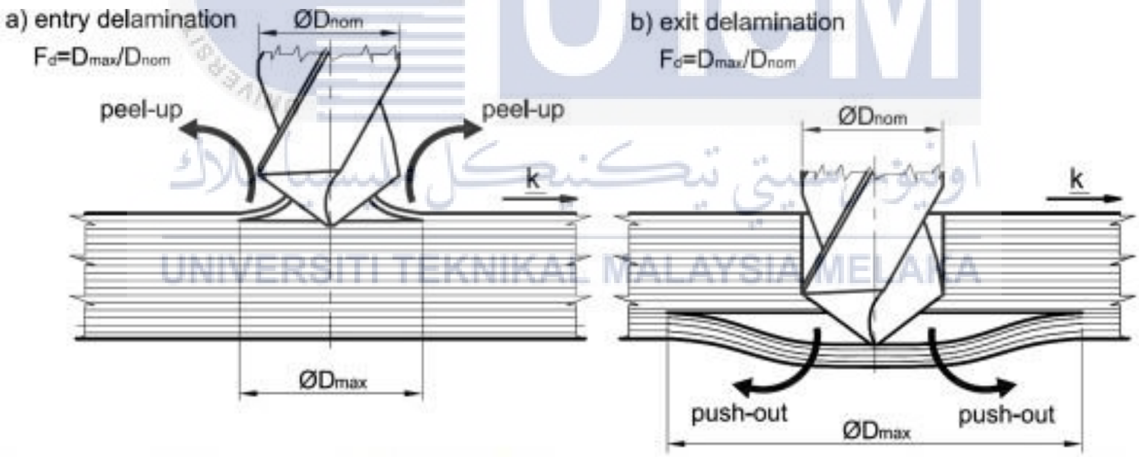

Figure 2.2 Peel-up and push-out delamination effects caused by drillingprocess of CFRP

2.2.1 Similar Utilizations of Robotic Manipulator on Different Task

There are tasks that also utilize robotic manipulator as their actuator on completing the task given. Tasks such as deburring, palletizing and assembly are among the tasks that often use robotic manipulator in their process.