UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION ON TOOL PATHS PROGRAMMING STRATEGIES USING CATIA V5 TO FABRICATE BIOMEDICAL APPLICATION ON SIMULTANEOUS FIVE-AXIS CNC MILLING MACHINE

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

by

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DECLARATION

I hereby, declared this report entitled "Investigation on Tool Paths Programming Strategies Using CATIA V5 to Fabricate Biomedical Application on Simultaneous Five-Axis CNC Milling Machine" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours. The member of supervisory is as follow:

………………………………………………………………….

(MOHD RAZALI BIN MD YUNOS)

ABSTRACT

In this project, information's, journals and article regarding CAD/CAM biomedical part and five-axis machining tool path have been searched for better acknowledgment and understanding. In this study, femoral knee part was selected to be machined by five-axis CNC machine with two types of tool paths programming strategy which are isoparametric and multi-axis sweeping. The sculptured surface on the femoral knee part was selected as the studied surface as it proves to be the most challenging area to be machined. Objectives of this research are to determine the best tool paths programming strategy in producing femoral knee part utilizing CATIA V5 and dimensional accuracy is investigated. The femoral knee part CAD model has been selected from GrabCAD. The modification has been done based on the limitation of equipment and raw material. Aluminium 7071 is used as raw material to machine femoral knee part. DMU eVo 60 is used in machining the femoral knee part and machining program has been done using CATIA V5 software. Analysis of the machined femoral knee part was carried out using a Rexscan cs2 3D scanner device. Comparison between scanned data and CAD model has been done using Geomagic Control X. Related information of the dimensional accuracy is illustrated by a different type of colour. Blue colour indicates overcut while red colour shows undercut. Some recommendation such as using Coordinate Measuring Machine (CMM) as the measuring machine has been suggested in part of future work.

Keywords: Biomedical; Five-axis Tool Path; CNC Machine; CATIA V5, Accuracy

ABSTRAK

Dalam projek ini, maklumat, jurnal dan artikel mengenai bahagian biomedical CAD / CAM dan laluan alat pemesinan lima paksi telah dikumpul untuk mendapatkan pengiktirafan dan pemahaman yang lebih baik. Dalam kajian ini, bahagian lutut femoral dipilih untuk dimesin oleh mesin lima paksi CNC dengan dua jenis strategi pengaturcaraan alat yang merupakan isoparametrik dan pelbagai paksi menyapu. Permukaan yang diukir pada bahagian lutut femoral dipilih sebagai permukaan yang dikaji kerana ia menjadi kawasan yang paling mencabar untuk dimesin. Objektif kajian ini adalah untuk menentukan strategi pengaturcaraan laluan terbaik dalam menghasilkan bahagian lutut femoral menggunakan CATIA V5 dan ketepatan dimensi disiasat. Model bahagian lutut femoral telah dipilih dari GrabCAD. Pengubahsuaian telah dilakukan berdasarkan had peralatan dan bahan utama. Aluminium 7071 digunakan sebagai bahan utama untuk bahagian lutut femoral mesin. DMU eVo 60 digunakan dalam pemesinan bahagian lutut femoral dan program pemesinan telah dilakukan menggunakan perisian CATIA V5. Analisis bahagian lutut femoral machined dilakukan dengan menggunakan alat pengimbas 3D Rexscan cs2. Perbandingan antara data yang diimbas dan model CAD telah dilakukan menggunakan Geomagic Control X. Maklumat berkaitan dengan ketepatan dimensi digambarkan oleh pelbagai jenis warna. Warna biru menunjukkan terlebih mesin sementara warna merah menunjukkan terkurang mesin. Sesetengah cadangan seperti menggunakan Mesin Pengukur Selaras (CMM) sebagai mesin pengukur telah dicadangkan di bahagian kerja masa depan.

DEDICATION

I dedicate my dissertation work to my family and all my friends, a special feeling of gratitude to my loving parent, Azlan Bin Abdul and Suriah Binti Abdul Samad who always gives encouragements and positive vibes whenever I am needing it the most. Also not to be forgotten, much love for my siblings who kept me going with their own success in their respective studies and work. And also big thanks to all my friends for their non-stop support and contribution in many ways for this research. Praying the best of luck for all of you in everything you will go through later in life.

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CAM	-	Computer-Aided Manufacturing
CAD	-	Computer-Aided Design
CATIA	-	Computer-aided three-dimensional interactive application
NC	-	Numerical Control
CNC	-	Computer Numerical Control
STEP	-	Standard Exchange of the Product Model
STL	-	Standard Triangle Language
UTeM	-	Universiti Teknikal Malaysia Melaka
CAE	-	Computer Aided Engineering
CAT	-	Computerized Axial Tomography
RP	-	Rotating Platform
PS	-	Posterior Stabilized
WPC	-	Workpiece Coordinate
CR	-	Cruciate Retaining
CMM	-	Coordinate Measuring Machine

CHAPTER 1

INTRODUCTION

1.0 Background

Nowadays, the industry of manufacturing is growing rapidly due to the increase in demand, in accordance with the technological evolution. Some of the company opted to use the most advanced technology available in the market to fulfill the production demand, and it comes with pro and cons. Due to the very high cost of early computers and to the unique mechanical engineering requirements of aircraft and automobiles, large aerospace and automotive companies were the earliest commercial users of computer-aided design (CAD) software (Patrick Waurzyniak, 2007).

Shorter value creation chains and higher degrees of component accuracy have helped ignite the trend toward the complete machining of complex workpieces on a single machine. Standard machines are increasingly capable of taking on intelligently expanded technology combinations that promise to optimize piece cost and machine availability. These criteria's are complemented by the use of the five-axis machine (Michael Defer, 2016).

First and foremost, the computer numerical control (CNC) machining is the physical machining processes. Its part mechanical dimensions are created by the use of CAD software. It is then translated by the computer-aided manufacturing (CAM), which functions to generate NC programs. The generated numerical control (NC) program is then loaded to the CNC machine, which later will produce the desired part using specific cutting tools and cutting strategies.

There are few problems occurred in manufacturing industries especially in high precision machinings such as high setup time, tight accuracy and final surface finish quality. High setup time occurred because most of the companies are required to modify the G-code program manually. Machine downtime is equal to cost and should be reduced to achieve higher productivity. It is crucial for the machinist to understand the significance of the post processor and how it can affect the selection for the production process. The link between the CAM system and the NC machine tool is determined by the post-processing as each CNC machine will require one dedicated post-processors. The CNC machines involve two main components. The first one is the machine tool itself with its spindle, multiple or attachable heads; table; pallet changer; and machine axes that combine linear and rotary axes. Second, the CNC machine involves G-code reading or conversational language which is used to program the machine. Its task is to translate the NC program into axis movements and machine events (Roberts and Hmm, 2017).

There are many types of CNC machines. The two most common CNC machines in the metalworking industry are:

- Mills or machining centers (Figure 1.0): Generally, the workpiece is held on the table while cutting tools perform their work.
- Lathes or turning centers (Figure 1.1): A workpiece spins as the cutting tools are brought in contact with it. Lathes create symmetrical pieces

Figure 1.1: A CNC mill, often called a machining center, holds a part while a rotating tool cuts metal.
(adapted from Tooling U, 2015)

Figure 1.2: A CNC lathe, often called a turning center, rotates a workpiece while a tool cuts metal.
(adapted from Tooling U, 2015)

When talking about five-axis machining, it gives chills to the people, especially to the potential customer. The complexity of the machine is thought to be very advanced and complicated when compared to the older type such as the 3-axis, or other machining processes or method. As stated by Mike Cope (CNC Machining Blog, 2013), both three-axis and five-axis have many similarities in its processes. Both machines require the part to be placed on the table with jig and fixtures and a specific location on the part is selected as the zero reference point or origin for the program. For most of the users, they already understand the concept of single setup vs multiple setups, manual removal for flipping the part, and the concept of relocating the origin point for a specific side of the part. But they still feel unconfident as they cannot see the full details of each procedure for the features and how to do it.

1.1 Problem Statement

Complex geometry requires multiple setup or process**.** Biomedical part machined from bar stock requires a lot of material to be removed, resulting in an expensive process because of the low machinability rating of many of the materials involved. As a result, some parts are cast to near net shape, and that often requires fixturing that is complex and expensive (Benes, 2006).

Accuracy is one of the most crucial aspects of any biomedical parts as any imperfection will cause health hazards. As most of the biomedical have complex geometry and contours, it will suit with the capability of the five-axis CNC milling machine. Sharp edges or inside radii on any implant must be justified. Any failure will serve as a stressor to the implant activity and noticeable in premature failure in a poorly designed implant (John McCloy, 2016).

One of the major issues with 'Off-the-Shell' implant, which is a limited range of standard sizes, is that it would not fit the patient properly. It is like having one shoe design that only comes with five or six sizes in the shop. A study published in the journal Pain in 2011 establish that three to four years after surgery 44 percent of 632 knees and 662 hip patients described the persistent pain (Jonathan Gornall, 2016).

1.2 Objective

The objectives of the project are:

1. To determine the most suitable tool paths (multi-axis sweeping/isoparametric) for biomedical part.
2. To produce a real machined femoral part using the most suitable tool paths.
3. To investigate the effect of the dimensional accuracy of a machined part to be compared to the initial CAD data.

1.3 Scope

The ultimate concern of this research is to determine the most appropriate machining tool path generations in producing biomedical part blade utilizing CATIA V5 as the main CAD/CAM software. Material that will be used in validating the tool path for the physical machining is Aluminum 7071. 3D CAD model of any related biomedical parts shall be searched through few resources available namely reverse engineering method (RE), common creative sharing website or nearby industries who are willing to collaborate in this research.

There are plenty of techniques that can be used to produce the part, but its suitability should be considered first, with the use of CATIA V5 software. The machine that will be used to perform the machining is five-axis CNC milling machine (DMU 60 eVo). The accuracy of the finished part will be analyzed later on with the use of 3D scanner and metrology.

CHAPTER 2
LITERATURE REVIEW

2.0 Five-Axis Machining

Shops all over the country are investing in 5-axis to increase profit margins on parts they previously were producing on 3-axis machines. CNC technology continues to accelerate. It's difficult to figure out what matters and what doesn't when it comes to new features and new processes. The technology surrounding 5-axis machining can be even more difficult to digest, especially if certain companies don't yet have a 5-axis machining center (Mike Cope, 2017).

Basically, the 5-axis works on the concept of Cartesian coordinate system, which represented by the variables X, Y, and Z. The other two can be described as orientation. The fourth axis is A: rotational axis around X, while the fifth axis is B: rotational axis around Y. The last axis is C, which rotates about the Z-axis (Figure 2.0).

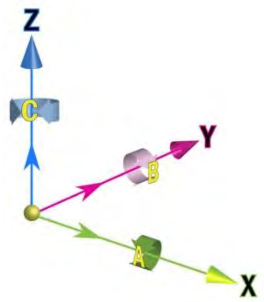

Figure 2.1: Axes of five-axis machining.

Sources:

(http://www.engineering.com/AdvancedManufacturing/ArticleID/11930/The-What-Why-and-How-of-5-Axis-CNC-Machining.aspx)

The A, B, and C axes are ordered alphabetically to match with the X, Y and Z axes. While there are 6-axis CNC machines, such as Zimmermann's FZ 100 Portal milling machine, five-axis configurations are more common, whereas the addition of the sixth axis typically offers few other assistance.

Last, about axis-labeling conventions: in a vertical machining center, the X- and Y-axes exist in in the horizontal plane while the Z-axis exists in in the vertical plane. In a horizontal machining center, the Z-axis and Y-axis are inverted (Figure 2.1). (Ian Wright, 2016)

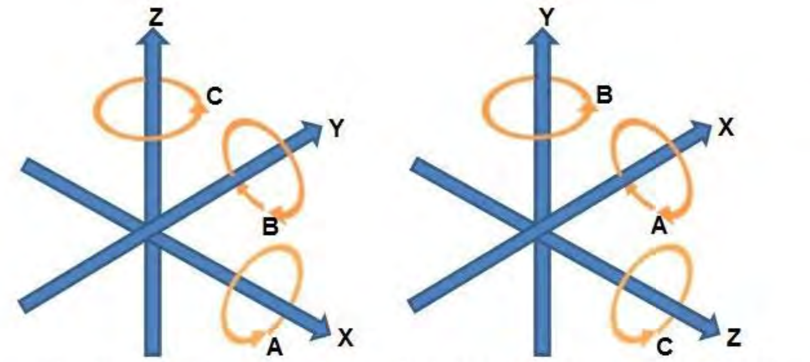

Figure 2.2: Vertical Machining Center and Horizontal Machining Center Axes

Sources:

(http://www.engineering.com/AdvancedManufacturing/ArticleID/11930/The-What-Why-and-How-of-5-Axis-CNC-Machining.aspx)

Despite the fact 5-axis machining is more popular to be linked with complex geometries, it is much more common that 5-axis machines are used for five-sided machining in order to cut setup time and reduce the typical flipping of parts which is necessary on three-axis machining centers. At the end, the manufacturer will able to increase the profit margin per part, and also increase the accuracy of the machined part, switching from moving parts around on standard or conventional machine to single mounting on the 5-axis machining center (Ann et al., 2011).

Using cubical workpiece as an example for machining a certain part, it should contain five faces to be machined (Figure 2.2).