UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FIVE-AXIS TOOL PATH PROGRAMMING UTILIZING CATIA V5 FOR TURBINE BLADE: ALUMINIUM 6063

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

by

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2016

DECLARATION

I hereby, declared this report entitled "FIVE-AXIS TOOL PATH PROGRAMMING UTILIZING CATIA V5 FOR TURBINE BLADE: ALUMINIUM 6063" is the results of my own research except as cited in references.

Signature : ………………………

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APPROVAL

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

……………………………….

(SYAHRUL AZWAN BIN SUNDI @ SUANDI)

ABSTRAK

Melalui kajian ini, semua maklumat, jurnal, artikel yang berkaitan dengan CAD/CAM, turbine blade dan five-axis machining pergerakan mata alat bagi peningkatan pengetahuan tentang projek ini. Pada masa kini, sesetengah masalah telah dihadapi berdasarkan turbine blade seperti kecacatan atas sebab manufacturing process. Objektive bagi projek ini ialah mengeluarkan give-axis machining pergerakan mata alat yang sesuai serta ketepatan bagi machined part. CAD model telah didapati dari GrabCAD. Perubahan telah dijalankan berdasarkan peralatan dan bahan mentah yang sedia ada. Aluminium 6063 telah digunakan sebagai bahan mentah bagi turbine blade. Five-axis machine yang code DMU 60 monoBLOCK telah digunakan bagi menghasilkan turbine blade serta strategi pemesinan telah disediakan melalui CATIA V5. Dalam CADCAM software, ,beberapa strategi telah digunakan seperti roughing process, multi-axis flank contouring, multi-axis sweeping dan isoparametric. Selepas proses pemesinan fizikal, penilaian telah dijalankan 3D Scanner serta its methodology. Keputusan yang didapati dari 3D Scanner telah dinyatakan perbezaan CAD model dengan bahagian dimesin fizikal melalui warna yang berbeza. Warna biru mewakili kelebihan pemotongan serta warna hijau mewakili kelebihan bahan.

Kata Kunci: Turbine Blade; Five-axis Pergerakan Tool; Mesin CNC; CATIA V5; Ketepatan

ABSTRACT

In this research, information's, journals and articles regarding CAD/CAM turbine blade and five-axis machining tool path have been searched for better acknowledgement and understanding. Currently, some problem has been occurred in turbine blade such as premature failure of blade caused by serious manufacturing defects. Objectives of this research are producing suitable machining cutting tool path utilizing CATIA V5 and accuracy is investigated. Turbine Blade CAD model has been selected from GrabCAD. Modification has been done based on limitation of equipment and raw material. Aluminium 6063 is used as raw material to machine turbine blade. DMU 60 monoBLOCK is used in machining turbine blade and machining program has been done by CATIA V5. In CADCAM software, machining strategies have been used to machine turbine blade are roughing process, multi-axis flank contouring, multi-axis sweeping and isoparametric. After physical machining process, analysis has been done through 3D Scanner and its methodology. Result from 3D Scanner show comparison between CAD model and physical machined part by different type of colour. Blue colour shows overcut while green colour shows undercut. Some recommendations such as smaller and tapered cutting tool has been suggested in part of future work.

Keywords: Turbine Blade; Five-axis Tool Path; CNC machine; CATIA V5; Accuracy

DEDICATIONS

To my beloved family

ACKNOWLEDGMENTS

Firstly, I would like to thanks to my beloved university, Universiti Teknikal Malaysia Melaka (UTeM) giving me this opportunity to explore myself in new thing. I would like to thanks God for blessings to allow me complete my Final Year Project smoothly although there are some problems faced in Final Year Project.

I wish to express my fully thanks to my Supervisor, Mr. SYAHRUL AZWAN BIN SUNDI @ SUANDI and co-supervisor Mr. MUHAMMAD SYAFIK BIN JUMALI for the motivation, enormous amount of knowledge and patience. Both of supervisor have guide me and give useful information in all the time of research study.

Besides, I like to take this opportunity to express my gratitude to all assistance engineers in UTeM which given fully assistance to me for this research study.

Last but not the least; I here to thank my family and friends for the continuously encouragement, care and support me toward this project.

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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
Ksi	=	Kilopound per square inch
IGES	=	Initial Graphic Exchange Specification
STEP	=	Standard Exchange of the Product Model
STL	=	Standard Triangle Language
UTeM	=	Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 Background

In current condition, there is a great importance in productive activity which is machining process for both indirectly for the manufacture of auxiliary elements and directly in the manufacture of components. Multiple fields related to the machining technology has evolved much in recent years such as the means of production, machining technology, tools for cutting, CAD/CAM or the sensors. Technique that applied in five-axis machining have been evolved rapidly with many CAD/CAM software developers. CAD/CAM software have addition function such as collision-avoidance capabilities and advanced simulation for five-axis program. CAD/CAM software is designed to cut the complex parts used in many areas such as die-mold, aerospace and medical machining applications. (Patrick Waurzyniak, 2007).

CNC machining means the physical machining process which is controlled under a NC program. A programmer must specify machine activity in NC program and cutting tool movement based on the sequence of the machining process. NC program execute instructions and interpret it through the machine control unit (MCU) of the NC machine. There are three types of NC programming which are manual programming, CAD- assisted programming and computer-assisted programming which based on the level of automation.

CAD systems is used to define, edit and verify the actual cutter motion and also to define the part geometry. This system can help in achieved high performance levels of automation. Nowadays, there are several CAD/CAM systems support the capability to generate instructions of NC machining which based on the definition of geometry for a cutter and workpiece, such as CADCAM, CATIA and Computer vision.

Delcam plc (Birmingham, UK) has been develop CAM software and also made moves on the acquisition front, purchasing IMCS Inc. PartMaker (Fort Washington, PA) after their company buys Engineering Geometry Systems (Salt Lake City), developers of FeatureCAM. (Patrick Waurzyniak, 2007)

Recently, five-axis and multi-axis machining methods have been looked by CAM software suppliers to solidify their offerings for users trying to stay competitive by using more complex manufacturing techniques. In getting keen interest in multi-axis and five-axis machining, there are manufacturers who play important role such as Eastern European and Asian manufacturers. Aim of those manufacturers are getting lower cost for tools used in five-axis machine tools and intense competition from low-cost. To reduce setups on machining complex parts, new five-axis offerings add the ability.

Infinite probability things such as to shapes and the part sizes which can manufactured effectively by five-axis machining. The cutting tool on a center of five-axis machining moves across the linear axes which are X, Y and Z axes together with rotates on the B and A axes to machine the workpiece/ part from any direction. On the other hand, five-axis machining can manufacture five sides of a single part in single settings. (Mazak) Based on explanation of Gibbs (Rolls-Royce), Five-axis technology provides the user with the ultimate amount of control when applying tooling to a part. Because of this, collision avoidance, improved surface finish, and reduced tool wear are some of the benefits realized. (Stuart Nathan, 2015)

One of the leading solutions for product success is CATIA V5. CATIA V5 is a software that addresses all organizations related with manufacturing field which from minor independent manufacturer until their supply chains. CATIA software is suitable to a wide variety of industries such as industrial machinery and automotive, aerospace, electronics, building of ship, consumer goods and plant design. Nowadays, one of function using CATIA is designing anything in the world which from a clothing and jewelry to an airplane. Product engineering in a fully-integrated manner with functional range and power is provided by CATIA to obtain the complete product development process. CATIA helps to increase response of enterprises to market needs shorten development cycles and facilitates reuse of product design knowledge.

An old method to create turbine blade was metalworking. To create turbine blades used for jet engines, the most basic and ancient methods of metalworking are casting process. If a fire can be heated until temperature which can melt a metal, a crucible is created to melt metal together with a mold (can withstand the heat) and cast complex forms of metal. “The blades operate in an environment several hundreds of degrees hotter than the melting point of the nickel alloy, but because of the cooling mechanisms, the metal is never above its melting point, even though the environment is.” (Neil Glover, Rolls-Royce). Not all material in making turbine blades is nickel alloy; family of alloys and ceramic materials also used in making turbine blades. A significant differentiation between temperature of external flow and surface temperature. Material with a high melting point is used in solving the problem and reduces the effective temperature over the surface of the used metal. (Stuart Nathan, 2015)

In the periodic table, the 13^{th} element is aluminium which is a silvery-white metal. Aluminium is the metal that widely disseminated on Earth. This statement can be proved as more than 8% of the Earth's core mass is aluminium. After oxygen and silicon, the third most common chemical element on earth is aluminium. (Ivan Aivazovsky) There are increasing requirements for those projects which involved aluminium have become more familiar as aluminium has become an excellent alternative method of steel. In welding fabrication industry, many applications are applied together with the growth of aluminum. The advisable way to understand aluminium clearly is starting by become familiar with the aluminum designation system/ identification. Currently, many types of aluminum alloys are available and have their characteristics. Nowadays aluminum alloys make up a wide and multifunctional range of manufacturing materials which together with their various tempers. The difference between many available alloys and their various properties is very important step for optimum product design. (ESAB knowledge center). One of aluminium alloys is 6xxx series are combination aluminium with silicon and magnesium. 6xxx series aluminium alloys are moderate in strength which is 200 to 350 MPa. Though the heat treatment processing or forming process, the strength of aluminium 6xxx series are achieved. (sapa:)

1.2 Problem statement

At present, one of causes failure of blade is manufacturing defects. Defects often occur as design specification of blades which based on CAD models or drawings are not follow during manufacturing process. One of the common defects is premature failure of blade as it is weakening the point that normal loads by serious manufacturing defects.

Turbine blades are designed for mass center location and optimum aerodynamics, resist extreme temperature, and avoid corrosion, and constitute of advanced metal alloy castings and composites to increase strength. Tight tolerances apply to both the geometry and alignment of turbine blades to guarantee optimum blade position and aerodynamic operation. (Nikon)

Currently, process of manufacturing turbine blades are castings, forgings, solid billets of titanium and stainless steel or bar stock. (Mark Albert ,2012) Many factors are important such as total cut time, depth of cut, spindle speed, an investment in the machine itself and tool life in determining material of manufacturing process. These factors contribute to cost of manufacturing and in turn the ability to efficiently and profitably machine selected material.

By machining, manufacturing defects of turbine blade may be reduced. Five-axis CNC machining is suitable to machine complex part. Five-axis CNC machining provides a high quality of product or part and given good positional accuracy. Simulation done in software such as CATIA V5 helps in determining defect occur before physical machining. This step helps in preventing wasted material.

1.3 Objectives

The objectives of this project are stated as below:

a) To determine the suitable machining tool path in preparing the CAM program for a turbine blade utilizing CATIA V5 by validating the tool path in the real machining which is 5-axis machine.

b) To investigate the effect of dimensional accuracy of a machined part in transferring the CADCAM data to the actual machined part.

1.4 Scope

In this research, things included and limitations of this project are discussed. There are limitations in this project as it is impossible to include everything in the project. This project is concerned on getting the suitable machining tool path generations in producing one turbine blade utilizing CATIA V5 as the main CAD/CAM software. Material used in validating the tool path for the physical machining is Aluminum 6063. CAD model of turbine blade is searched and verified by adviser. This step is very important in ensuring that the chosen CAD model fulfil the project requirement. Various five axis tool paths/ processes designed to obtain desired turbine blade. Processes that been selected in this research are roughing multi-axis sweeping, multi-axis flank contouring and isoparametric. Five-axis machine DMU 60 monoBLOCK is used to perform the machining. Accuracy of machined part has been analysis after physical machining. 3D Scanner which located in Rapid Prototyping Lab is used. 3D Scanner can provide fast and good accuracy result which shows comparison machined part with the original CAD model and define them based on different type of colour. Dimensional accuracy is important factor in machining turbine blade.

CHAPTER 2

LITERATURE REVIEW

2.1 Five-Axis Machining

A study which related with a new method for five-axis tool path optimization has conducted by Pascal Ray (2008) found that there is remaining some kinematic performance issues that have been introduced by tool path computation which can generate slowdown although scientific community has been study the main problems of five-axis. The goal of this study is to improve machine tool behavior without deterioration of milled part quality. The kinematic behaviour of the machine tool and the five-axis machining geometric method is necessary be confronted. There are a lot of researched in five-axis machining are focusing on methods to figure out tool axis orientation in order to improve or optimize such as:

- ❖ The control of interference between part and tool
- ❖ The quality of the milled surfaces is evaluated.
- ❖ The interpolation format of the tool path
- ❖ Free collision positioning of the tool under its environment

As mentioned in chapter one which is introduction, one of purpose of free-form surface machining is to minimize machining time while machining complex shapes that respect to the level of quality. Machine tool behavior and milling strategies are leading to achieve those aims of productivity and quality. The study proposed by Pascal Ray (2008) was dealing with the relation between productivity and quality. The method presented in this study is minimization the angular difference between curvature and two successfully tool axis orientations. After that, this method is applied to the rotation axis coordinates. The optimization of this study is a minimization of the movement which created by each rotation axis.

The findings of the study written by Hsin-Pao Chen et al. (2009) can help in removing tool marks of blade surfaces through smoothing five-axis point milling cutter paths. Machining controlled by five-axis is certain manufacturing strategy to get a centrifugal compressor impeller efficiently which have characteristic that overlapping, surface texture and complex geometry with a specified dimensional tolerance. There are two challenge tasks needed during planning five-axis tool paths to mill impeller. Those tasks are required as they play role as part in the manufacturing process. Planning of tool paths in milling impellers by five-axis has faced one challenge part is making decision or linearization problems by suitable CL data without causing local gouge and global interference due to the curvature limitation between the impeller surfaces and cutter size. Another challenging that has been mention is CL data need to be further convert into NC data which depend on the setting of a selected five-axis machining tool. This study had focus on the reverse moving movements on axes along five-axis tool paths. Besides, the step of eliminating a gouge phenomenon on impeller surfaces is presented through five-axis CNC machine. During finishing process of milling centrifugal compressor impeller, tool path of linearization problems and reverse movements of moving axes along a five-axis without interference may causes tool marks leaved by cutter on the surfaces of impeller. Its three linear axes are used to machine an impeller by a common five-axis machine tool as guidance for its tool to specified CC (cutter contact) points which are to be milled on impeller surfaces. Besides, to adjust its axis of cutter to prevent collision, the two rotational which are rotating axes and tilt angle of the five-axis machine tool are utilize. In this study, to machine centrifugal compressor impellers is generated without any tool marks leaved on machined blade surfaces, a useful and reliable procedure which can be utilized has been established. There is a simple way which is the procedure can be used conveniently in determining initial five-axis accessible tool paths for roughing and semi finishing process in condition of considering a ball end mill and an end mill. Five-axis finish milling of an impeller consider successful as it does not leave tool marks on impeller surfaces, the effectiveness of this procedure has been experimentally confirmed. Demonstration by an experimental machining test which referred to a popular configuration of five-axis machines have been done to verification of the algorithms and implementation of the procedure. The time of machining can be saved up to 23.57% with the spline tool paths. The proposed procedure can simply be modified to fit them for others five-axis machines with two rotational axes and three orthogonal translating axes. Thus, the future topic which can be discussed is the effect of machined impeller blade surfaces through reverse axes movements of five-axis machine tools. Figure 2.1 shows the pressure surface after removing tool marks in this finding while figure 2.2 shows model that has been used in this finding which is impeller.

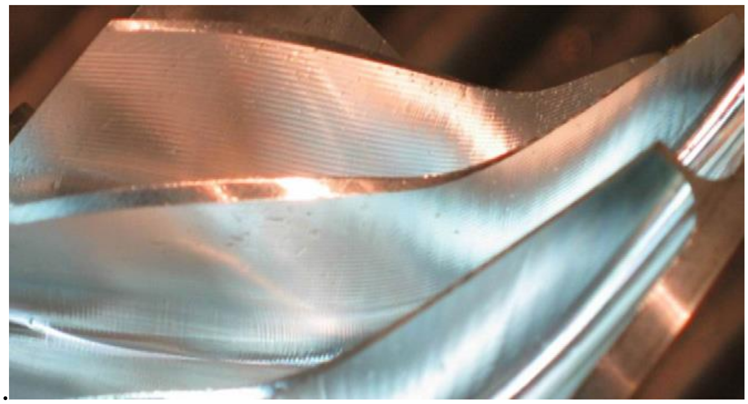

Fig. 2.1 The Pressure Surface after Removing Tool Marks
(adapted from Hsin-Pao Chen et al. (2009))

Fig. 2.2 Impeller that been Machined.
(adapted from Hsin-Pao Chen et.al (2009))

Linjian Yang and Jinchun Feng (2011) identified some factors need to be considered when selection of the tool. For different types of machining efficiency and accuracy requirements in the certain environments, different machine tools are chosen. In selection of tool, some parameters such as cutting parameter that related to blade and tool, machine power, the speed of milling material of blade and head are needed to be calculated. In addition, arbor, blade, cutter head and milling head need to be simulated and have interference checking depending on posterior simulation processing. Processing method and Cutter scheme needed modification while cutter interference exists. Finally, it must be ascertained that cutter has no problem in interference examination and simulation. In a follow-up study, Linjian Yang and Jinchun Feng (2011) also found that, in the machine power, machine tool stiffness and speed range of milling head must be sufficient during simulation. Different diameter cutters are utilized with these conditions to improve the efficiency of machining by calculating suitable diameter. At the same time protection of machine tool is paid attention.

Besides, selection of the parametric curve of tool trajectories as the machining direction of milling when machining blade profile is one of study done by Linjian Yang and Jinchun Feng (2011). This step helps to improve capability of cutting technology. Different knife-axial controlling methods and cutters are applied in different areas to improve efficiency of as possible. Based on simulating machining techniques, key techniques are proceeded with the development of computers. On the other hand, there are more preface needed to be consider regarding automatic programming when five-axis CNC machine is used to machine large blade. Verification of the simulation on computer is important step before machining. This step can be repeated modification and optimize processing scheme by machining simulation. Assembling precision in making uniform welding amount can be greatly improved through the CNC processing way of groove.

In process a machine tool or CAD/CAM technology is purchased, an important investment is required and it cannot be done without attentive consideration. Precision, flexibility and productivity will be limit as technology selected incorrectly. (Arslan etal.,2004), so companies usually pay attention on technical capabilities and performance than cost. Comparision between three-axis and five-axis CNC centers in free-form machining has been done. (WojciechZębala and MalgorzataPlaza ,2014) This information are useful although although hard material is not used in this project. This