UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

COMPARING ACCURACY, SURFACE ROUGHNESS AND REPEATABILITY STUDY OF TORQUE LINK AEROSPACE LANDING PART ON FIVE-AXIS SIMULTANEOUS MILLING (LINEAR) AND FIVE-AXIS SIMULTANEOUS MILLING (HIGH SPEED) BY USING CATIA V5

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SESI PENGAJIAN **2018/19 Semester 2**

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

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Date :

DEDICATION

To my beloved parents

ABSTRAK

Pada masa kini, mesin CNC digunakan secara meluas dalam sector pengeluaran dan perkilangan terutamanya bidang automotive dan aeroangkasa. Dengan mesin CNC menghasilkan bahagian dengan lebih tepat berbanding proses operasi manual. Terdapat konfigurasi mesin CNC yang terdiri daripada berbeza sistem paksi. Tujuan kajian ini adalah untuk membandingkan ketepatan dan kekasaran permukaan terhadap dua lima paksi serentak mesin CNC yang menyenget meja/meja dan menyenget meja/kepala. CATIA V5 telah digunakan sebagai simulasi pemesinan perisian CAM untuk menghasilkan strategi pemotongan dengan penggunaan komputer sebagai proses simulasi pemotongan sebenar. Rekabentuk pesawat lengan tork dihasilkan dengan penggunaan kedua-dua mesin CNC. “Coordinate Measuring Machine (CMM)” digunakan sebagai alat pengukuran dimensi terhadap hasil pemesinan lalu menganalisis keputusan geometri. Kekasaran permukaan diukur dengan menggunakan instrumen stylus selepas bahagian-bahagian dihasilkan.

ABSTRACT

Today, CNC machines are widely used in manufacturing production especially automotive industry, aerospace industry, and aircraft industry. With the CNC machines are produce part with more accurate compare to the manual operation process. CNC machines have different configuration and different type axis system. The aims of this paper describe the comparison accuracy and surface roughness of the two type of five-axis simultaneous CNC machine which are tilting table/table and tilting table/head. CATIA V5 is used as CAM simulation advanced machining software to control CNC machine and compute the tool cutting path strategy as simulating the real cutting process. Torque link aircraft design machining by using these two CNC machines respectively. Coordinate Measuring Machine (CMM) was chosen as the equipment for measuring the physical geometry dimensional accuracy of the machining parts. Surface roughness are measure by using stylus instrument after the parts are produces. Then analysis process to the results of the geometry parts.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AA- arithmetic average

Al_2O_3- Aluminum oxide

CAD - Computer Aided Design

CAM- Computer Aided Manufacturing

CATIA - Computer Aided Three-dimensional Interactive Application

CLA- center line average

CMM- Coordinate Measuring Machine

CNC- Computer Numerical control

D- diameter of tool(mm)

F - Feed rate (mm/rev)

FSD- Fixed Sensitive Direction

GRA- Grey Relational Analysis

N - number of teeth/ flutes

NC- Numerical control

Ra- Arithmetic mean value

Rq- Root mean square average

RTM - Resin Transfer Molding

S - spindle speed (RPM)

S - spindle speed (RPM)

UTeM - University Teknikal Malaysia Melaka

Vc - cutting speed (m/min)

π – pi

$f\ z$ - Feed per t

CHAPTER 1

INTRODUCTION

1.1 Background

In manufacturing system, conventional machine tools such as milling machine, lathes and drill presses are very familiar. Conventional machining requires high operator skill and training to produce high-quality parts on consistent basis. Today, conventional machine tools are replacing by Computer Numerical Control (CNC) machine due to human error and highly productive of CNC machine. By using the CNC machining, the process can be repeated and more accurate compare to manual machining. With the accuracy of CNC machining, the parts can produce is in the complex shapes compare to manual machining that impossible process. CNC Machining is used in the production of many complex three-dimensional shapes. It is because of these qualities that CNC Machining is used in jobs that need a high level of precision or very repetitive tasks.

In CNC, the software program is designated to operate the machines and to control an object. CNC machining is using G-cord to control the machines, then the cord is written to control the speed, feed rate and coordination. There are different types of CNC machines with various of configuration, with the standard axis which is X, Y and Z axis. CNC machine with more than 3-axis is advance which consist rotate function for the three basics axis which A is rotate around x-axis, B that rotate around y-axis and C is rotate around z-axis. Now, many configurations of CNC machines are produce due to can machining more complex parts as compared to 3-axis CNC machine.

CAD (Computer Aided Design)/ CAM (Computer Aided Manufacturing) Software is used to generate part designs and then CNC machining programs corresponding to part designs. The first rudimentary CAD/ CAM system were developed. At first, these software solutions were introduced by the same companies that develop the controllers. Soon after, enterprising individuals wrote their own CAD/CAM software. This technology will help the engineers to designs the part in a CAD software, then generate a toolpath in the CAM and then convert to G-code languages faster compare than another program. CAD software is the use of computer technology for design and design documentation. However, CAM software uses the models and assemblies created in CAD software to generate tool paths that drive the machines that turn the designs into physical parts.

There are various cutting parameters are used to increases the accuracy of product. Surface roughness also plays an importance role in surface finish of product after machining process. Surface roughness can affect the accuracy and to determining quality of the product when the demand increases. Spindle speed, feed rate and depth of cut of machining are the main role to determine the surface roughness value.

Torque links are important components for landing gear part for landing. Material composite are replacing the material steel to reduce its weight, cost of process and life of tool. There are new technologies are used to manufacture torque link which using fabrication techniques that call Resin Transfer Moulding (RTM). The function of this moulding is to increases the part mechanical properties that lower their viscosity for rational time.

In manufacturing process, repeatability process by using machine is widely use in any product to increases the demand of the customer. Through the repeatability process, the quality of the product will be decline. The aim of this study is the repeatability and comparison the aircraft torque link between two 5-axis CNC machines. Five parts need to produce for each machine and the result are analysis by using the stylus instrument.

1.2 Problem statement

The problem of this project has slightly similar research that comparison between configuration 5-axis simultaneous and 9-axis simultaneous. Lack of research for both different configuration 5-axis simultaneous. Insufficient of the research caused lack of real data to compare of these two 5-axis machines. Therefore, based on the configuration and advantage of machine to predict the result.

Based on the literature review and online source, it can make one simple prediction that the 5-axis tilting table and table is more accurate compare to the 5-axis tilting table and head with the same cutting parameter. This is due to my part is smaller and have inner hole that more suitable to table/table 5-axis machine which have secondary rotary axis in the form of a 360 degree and less number crunching during and after rotary axis moves.

The second problem is the surface roughness of the part is not depending on the 5-axis CNC machine. From the journal, online source and book state that the surface roughness is affect by the depth of cut, cutting speed, feed rate and the tools. Thus, lack of information that will the surface roughness depend on different configuration 5-axis machine. Thus, the result will be analysis based on this problem to make sure that the surface roughness is depend or independent to different configuration 5-axis machine.

1.3 Objective

i. To compare accuracy and surface roughness between 5-axis simultaneous tilting Table/Head and tilting Table/Table with same software and same parameters.

ii. To obtain the configuration of both 5-axis CNC machine.

iii. To generate tool path that drive the both 5-axis from the design to the product.

1.4 Project Scope

This project will focus on machining process for both 5-axis simultaneous. The same design is machining on two different configuration CNC machines which are 5-axis tilting Head/Table and tilting Table/Table. The material used in this project are the aluminium block for CNC milling machine. The part that I choose need to scale down the design and the choice of the tools are the obstacle to get the part accurate. Therefore, the size of stock of aluminium blocks are 120mm*40mm*15mm. By using CATIA V5 CAD/CAM software is carried out to generate tool path based on these two configurations of CNC machines. Then, convert the tool path to post-processor respectively. The same parameter is used on these two machines as the fixed variable for easily compare the machining accuracy. After the parts complete, the results are analysis by using stylus instrument, Vernier calliper and Coordinate Measuring Machine (CMM) to measure the surface roughness and dimension.

CHAPTER 2

LITERATURE REVIEW

2.1 Five-axis simultaneous CNC machine

There are five standard axes universally used in CNC machining. Every standard CNC machine must have linear motion along the X, Y, and Z axes. In most five axis machines have same structure with three linear axis machines with adding two rotary axes, which are added two axes, A, B or C. For 5-axis machine, there are 3 ways universal relative motion between the tool and the workpiece

1) Using a stationary workpiece and a tool with two swivel axes. (Tilting Head/Head) (Figure 2.1)
2) Using a stationary tool axis and a workpiece with a double swivel motion, for example, via a swivelling rotary table. (Tilting Table/Table) (Figure 2.2)
3) Using a tool axis and a workpiece that each have a swivel motion, offset by 90° relative to each other. (Tilting Head/Table) (Figure 2.3)

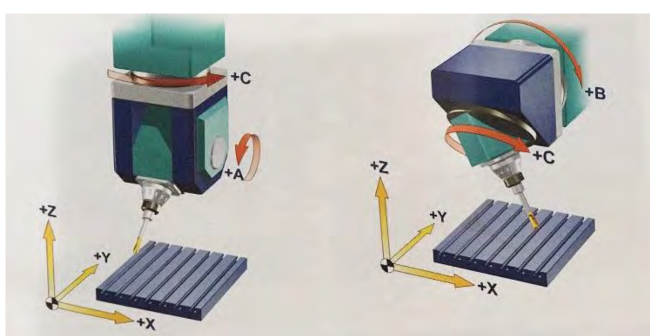
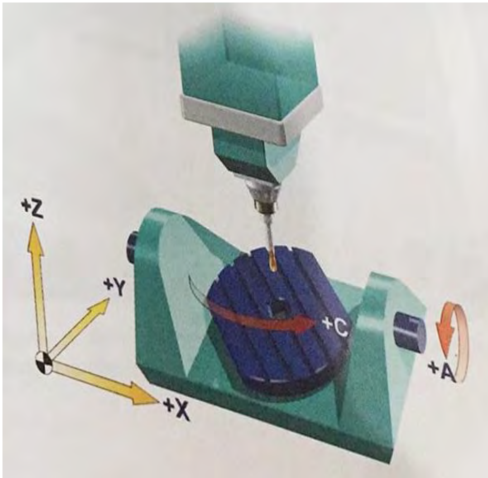


Figure 2.1 Tilting Head/Head 5-axis machine



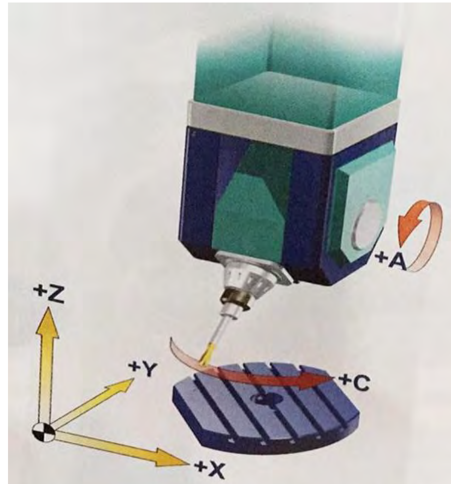


Figure 2. 2 Tilting Table/Table
5-axis machine

Figure 2. 3 Tilting Head/Table
5-axis machine

(Adapted from kief et al. (2013))

With this universal relative motion, the part can be approached from all directions and can be worked from five sides in a single operation. A-axis rotational at the around X, B -axis is rotate at the Y and C axis is rotate at the Z. (Figure 2.4)

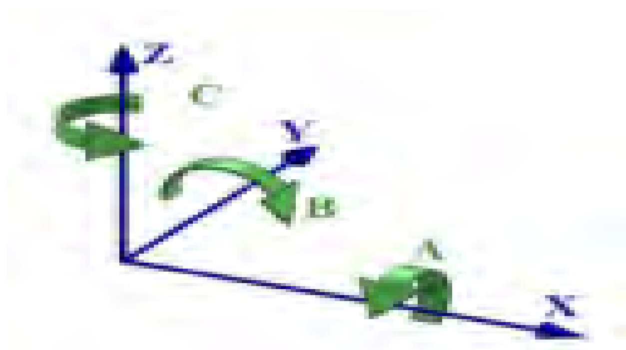


Figure 2.4 axis system
(Adapted from breaz et al. (2017))

According to breaz et al. (2017) state that when machine complex parts sometime one or even two supplementary rotational movements together with translation on X, Y and Z axes are needed. There are 2 types of 5-axis machine which include trunnion-style machine operate with A-axis (rotating about the X-axis) and C-axis (rotating about the Z-axis). However, swivel-rotate-style machine operates with a B-axis (rotating about the Y-axis) and a C-axis (rotating about the Z-axis). A trunnion style 5-axis machine have +110 rotates degrees and which swivel-rotate-style machine only have +92 rotates degree. Thus, Trunnion style 5-axis machine has unusual undercut capability. The swivel head can hold heavier parts than the trunnion style 5-axis machines because of the larger table.

However, my project is conduct swivel-rotate-style machine and trunnion style machine which are tilting table/head and table/table. For 5-axis machine configurations, it can divide into three categories: Head/Head, Table/Head and Table/Table. From the Head/Head 5-axis machine, the head can move around for manufacturing large parts. For this design, these machines have narrow travel in tilting and rotational axis.

For the Table/Head 5-axis machines, one is lathe basic and the other one is based on the milling basic configuration. This configuration is depending on the C and B axis located on the table or at the turning spindle. The rotating table only move around its own axis and supported by a steady rest. Weight of the tools is carrier by the spindle head due to handling the cutting pressures. There have limited range for tilting axis located in the head, while unlimited range for the rotary axis of the table. As the part sits on the rotary axis, this configuration is defined to the dimension of product it can produce. However, the advantage of this configuration over the head/head configuration is that the ability to incessantly rotate the part while not regard for reaching a limit. The design of this 5-axis machine can hold with the heavier because of the table doesn't tilt, the whole weight of the product is transferred directly down though the bottom of the machine and onto the floor. Due to the larger table, this type of 5-axis machine is more versatility compare to table/table 5- axis machine. For the Table /head 5 axis machine, the swivel head tilts the tool to minimizes tool interference. Besides that, better chip controlled can be achieve due to the table machine horizontally.

For the Table/Table 5-axis machine, the two rotary axes are located at the table. The B axis tilts and the C axis rotates the part. Linear motion is handled by the milling head. Tool length offset work the same way here as with any conventional 3-axis machine. On this machine, the part is rounded by the tool. The machine's rotary devices need to can handle the weight of the part and fixture. Rapid movements as an importance factor for this capability. With this configuration has the smallest work envelopes.

Bi et al. (2015) review that geometric errors of rotary axes are the basic errors of a five-axis machine tool. Touch trigger is used to make sure that are the same point at different rotation angle and influences the geometric error coupling effect.

According to the Yang et al. (2017) the position of the part on the table is the forces transfer to the rotary drives that name torque disturbances. They also show that the workpiece position of the part at the table of machine also effect the collision between part and fixture. Workpiece at the position on transference of disturbance forces is to guide to rotary tracking errors and five-axis contouring errors. It is shown that translational drives are receive cutting force directly, the workpiece position significantly modified the rotary drives to undergoes cutting torque.

2.2 Simulation method by using CATIA software

CNC Machine programming is the primary focus of CAD-CAM vendors. CAD is a computer technology that designs product or offers to edit and draft part while CAM is a programming process have cutting parameters and cutting toolpaths. CAM program is used to create the cutting paths for the material to cutting, the path is effective way for tooling and collect material for cutting speeds and feed rate. Modern CNC machine automation software (CAD-CAM) give a wide solution to 3, 4, 5-axis as well as Turing Mill and multitasking. Programming CNC machine can operate with three types of programming methods which are manual programming, conversational programming and computer aided manufacturing (CAM) system programming.

Manual programming techniques need to make sure understanding of basic CNC characteristic. With the technique, we can probe the different methods to generate CNC programs. Manual programming is the best when the part designs are simple and can use NC codes to perform. To ensure that the CNC machine can be execute, programmer need to develop the program in the same language.

Conventional programming is a quick, simple and direct method to program design parts. It is given a few of cycles to profile parts, drill holes, cut pockets and thread mill. Graphic and menu-driven functions are used to create conversational program. When the program is generated, programmer need to check whether inputs are correct. When finished, programmer can check the input of the tool path plot during the machining cycle through the CNC machine screen. When programming become complex, many programming cycles need to run and caused conversational programming takes many step approaches which is less efficient. Conversational controls enable programs to be entered without used of mathematics and take a lot of the tediousness out of programming. Conversational controls can dramatically reduce the time it takes the programmer to prepare the program as compared to manual programming.

CAM systems are best used when there are a variety of machines to program and it software provides a variety of toolpath cutting strategies that support roughing, semi-finishing and finishing. The process is completely automated to save time, reduce errors, increase efficiency and produce perfect workpiece. With a CAM system, programmer will have a computer to help with the preparation of the CNC program. The part geometry will be imported to the CAM system which to reduce the need for the programmer to determine the size of the part and shape. Programmer need to choose machining operations from a menu and specify the machining parameters in fill-in-the-blanks fashion. Once finished, the program will be transferred directly to the CNC machine tool then upload into the CNC machine and can be operating.

Klancnik et al. (2016) review that the proposed CAD/CAM model consists of two modules which are prediction and evaluation modules by refer to the Figure 2.5. Programmer can upload their part to the system so that it can manufacture the product on the machine tool. Second step that need to develop solution and post-processing module to machine tool controls. Such a recorded form is called G-code and the entire machining program is called the CNC machining program.

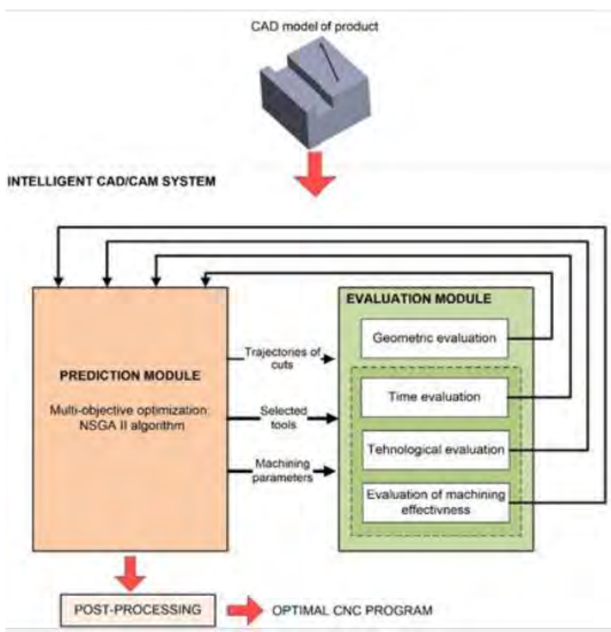


Figure 2.5: Model of an intelligent CAD/CAM system.
(Adapted from Klancnik et al. (2016)