UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# INVESTIGATION ON THE EFFECT OF MACHINING STRATEGIES ON THE SURFACE FINISH AND DIMENSIONAL ACCURACY OF FIVE-AXIS FLANK MACHINING OF CURVY ANGLED SHAPES (CONVEX)

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

by

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

TAJUK: **INVESTIGATION ON THE EFFECT OF MACHINING STRATEGIES ON THE SURFACE FINISH AND DIMENSIONAL ACCURACY OF FIVE-AXIS FLANK MACHINING OF CURVY ANGLED SHAPES (CONVEX)**

SESI PENGAJIAN: **2014/15 Semester 1**

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I hereby, declared this report entitled "Investigation on the Effect of Machining Strategies on the Surface Finish and Dimensional Accuracy of Five-Axis Flank Machining of Curvy Angled Shapes (Convex)" 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 fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Process and Technology) (Hons.). The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

# ABSTRACT

Machining strategist is a 3D CAM product that generates optimum roughing and finishing CNC tool paths from the complex shapes generates by all major 3D modelling systems. This research mainly study about the machining strategies offered in Computer Aided Manufacturing (CAM) programming. In milling process, there are two types of cutting strategy which are point milling and flank milling. In this study, only the flank milling is main focused. The purpose of this research is to find the best machining strategies namely Tanto Fan, Combin Tanto, and Combin Parelm resulting the most accurate dimensional accuracy and surface finish. Those three machining strategies selected were the options of tool axis given by CADCAM software Catia. Furthermore, the simulation from Catia shows a little different and sometimes shows same result of simulation even though users have changed the selection of tool axis. Besides, users always confusing in selecting the most suitable tool axis. An actual sample called End Cap was selected and it was an actual aero-structural components. The type of raw material used was aluminium A6063. A6063 is one of the highest strength materials, commercially available alloys with fair corrosion resistance and machinability. Typically used for aircraft skins, cowls and structures. For analysis, Coordinate Measuring Machine and surface roughness test was used to identify the significant effect of the factors on the response. As for the result, the best machining strategies for the part sample based on the dimensional accuracy was Tanto Fan. Meanwhile, the best machining strategies suitable for the part sample based on the surface roughness was Combin Parelm. The results obtained relied on a few conditions that have been discussed in this report. The conditions are believed to have any chances to influence the result for this study. There were two possible factors that contributed to the mentioned result which was related closely to the tool trajectory and vibration during machining process.

# ABSTRAK

Kajian penyelidikan ini terutamanya tentang pengaturcaraan pemesinan (proses canai) dan dikenali sebagai ‘Computer Aided Manufacturing’ (CAM) pengaturcaraan. Dalam proses canai, amempunyai 2 jenis strategi pemotongan di mana menggunakan titik canai dan rusuk canai. Untuk kajian ini, hanya pencanaian rusuk akan memberi tumpuan. Tujuan kajian ini adalah untuk mencari yang parameter paksi alat yang dinamakan ‘Tanto Fan’, ‘Combin Tanto’, dan ‘Combin Parelm ‘memberi nilai dimensi yang paling tepat bagi sebahagian berbentuk lengkung. 3 parameter yang berbeza adalah pilihan untuk paksi alat yang diberikan oleh perisian CADCAM Catia. Secara teorinya, takrif bagi 3 parameter yang diberikan oleh Catia agak umum. Tambahan pula, simulasi dari Catia menunjukkan sedikit berbeza dan kadang-kadang menunjukkan keputusan yang sama simulasi walaupun pengguna telah berubah pemilihan paksi alat. Tambahan pula, pengguna akan menghadapi mengelirukan untuk memilih paksi alat yang sesuai. Nama sampel sebenar End Cap telah dipilih. Bagi sampel bernama penutup hujung yang dipilih, adalah salah satu komponen aeroangkasa yang sebenar. Sebab mengapa komponen aeroangkasa dipilih kerana industri seperti aeroangkasa, di mana komponen mesti dihasilkan dengan pasti, pada masa dan spesifikasi yang sangat tepat. Jenis bahan mentah yang digunakan adalah aluminium A6063. A6063 adalah salah satu material yang mempunyai kekuatan tertinggi. Kedudukan kebolehkerjaan yang rendah dan dikimpal sahaja oleh proses rintangan. Biasanya digunakan untuk kulit pesawat, cowls dan struktur. Untuk analisis, CMM dan kekasaran permukaan ujian telah digunakan untuk melihat kesan yang ketara satu faktor kepada sambutan. Berdasarkan analisis, parameter yang terbaik sesuai untuk sampel bahagian berdasarkan ketepatan dimensi adalah Tanto Fan. Sementara itu, parameter yang terbaik sesuai untuk sampel bahagian berdasarkan kekasaran permukaan adalah Combin Parelm .. Hasilnya telah diperolehi oleh bergantung kepada keadaan beberapa yang telah dibincangkan dalam karya ini. Keadaan ini dipercayai mempunyai apa-apa peluang untuk mempengaruhi keputusan kajian ini..

# DEDICATIONS

I would like to dedicate to my beloved parents, Md Din bin Hasan and Normawarti binti Ahmad because encourage me to do better in my life. Not to forget to my brothers who are always advising me especially in moment of crisis. Last for not list, I would like to thank for my friends and classmate because support and help me by giving useful information and opinion during this study was performed.

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In the name of Allah, the Compassionate, the Merciful, Praise be to Allah, Lord of the Universe, and Peace and Prayers be upon His Prophet and Messenger. With Grace and Blessing from Allah, I am Ahmad Syazili Bin Md Din from Faculty of Engineering Technology have succeeded in completing my final year project together with this thesis. First and foremost, I would like thank to Allah, because of His willing and Blessing, I have succeeded in completing this project. High appreciate to my supportive project supervisor, En. Syahrul Azwan Bin Sundi @ Suandi for his guidance during performing this project.

Special thanks to everybody who help me to accomplish this project. For all helpful lecturers and technician, thank for supporting me everything regarding this project, teaching me some new and valuable knowledge and providing me with great equipment while conducting this experiment.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| CAD | = | Computer Aided Design |
| CAM | = | Computer Aided Manufacturing |
| CNC | = | Computer Numerical Control |
| CMM | = | Coordinate Measuring Machine |
| WPC | = | Work piece Coordinate |
| WCS | = | Work piece Coordinate System |
| P/P | = | Post Processor |

# CHAPTER 1
# INTRODUCTION

## 1.0 Introduction

The purpose of this research is to investigate the effect of machining strategies that are offered by CATIA V5 as the CAD/CAM software which will be used. Tanto Fan, Combin Tanto, and Combin Parallelism are the strategies that going to be applied. Each option of machining strategy used is expected to give different results of machining process in term of surface finish and dimensional accuracy. In addition, this research also emphasize to actual part because of the typical problem that the industry faced is necessary to do several test cutting in order to release a product that satisfy the customer specifications.

5-axis CNC machining has been commonly used in manufacturing of complex geometries in automobile, aerospace, energy, and mould industries. This advanced machining operation provides better shaping capability and higher productivity compared to traditional 3-axis machining. 5-axis machining provides infinite possibilities as to the part sizes and shapes can effectively process. The term "5-axis" refers to the number of directions in which the cutting tool can move. On a 5-axis machining centre, the cutting tool moves across the X, Y and Z linear axes as well as rotates on the A and B axis to approach the workpiece from any direction. In other words, five sides of a part can be processed in a single setup. Nevertheless, manufacturing of complex workpieces is still difficult, although the 5-axis machining proposes a lot of new possibilities and advantages (López, 2005). In addition, the geometrical accuracy of 5-axis machine tools is also an important factor.

Machining strategist is a 3D CAM product that generates optimum roughing and finishing CNC tool paths from the complex shapes generates by all major 3D modelling systems. Machining strategist is a technological leader in this area with many unique machining strategies for generating world-class machining programs.

At the same time, many of these strategies can improve the productivity of older CNC machines with dramatically reduced air cutting time and programs with smooth arcs which help to maintain continuous machine tool motion. Machining strategist can take the machining capabilities to new levels and productivity to new heights. Machining strategist has been developed to be very easy to learn and use. Machining strategist includes, Z-level Roughing, Horizontal Finish Machining, Fixed axis and few other strategist.

The 5-axis machining operation contains two different milling methods: end milling and flank milling. The cutting edges near the end of a cutter perform the actual material removal in end milling while the circumferential part of a cutter mainly does the cutting in flank milling. Compared with point milling, flank milling has its unique advantages. It can increase the material removal rate, lower the cutting forces, eliminate necessary hand finish, ensure improved component accuracy and result in longer tool life. Thus, it offers a good choice for machining slender parts, like turbine blades and impellers. Recently, increasing attention was drawn into the problem of optimum positioning of the cutter for flank milling. The mechanism of this multi axis flank contouring is it uses the cutting tool body for mill the part. This requires an accurate computation of the tool orientation. Flank milling is therefore very interesting for the machining of developable surfaces, because this method is able to machine the surface accurately with a high level of productivity. By using flank milling or side milling techniques, the machined surface quality can be improved compared with using end milling techniques. Sometimes, the machined parts do not need a polishing process after flank milling and the machining efficiency can be improved a lot. The figure 1.1 shows the mechanism of cutting tool in flank contouring.

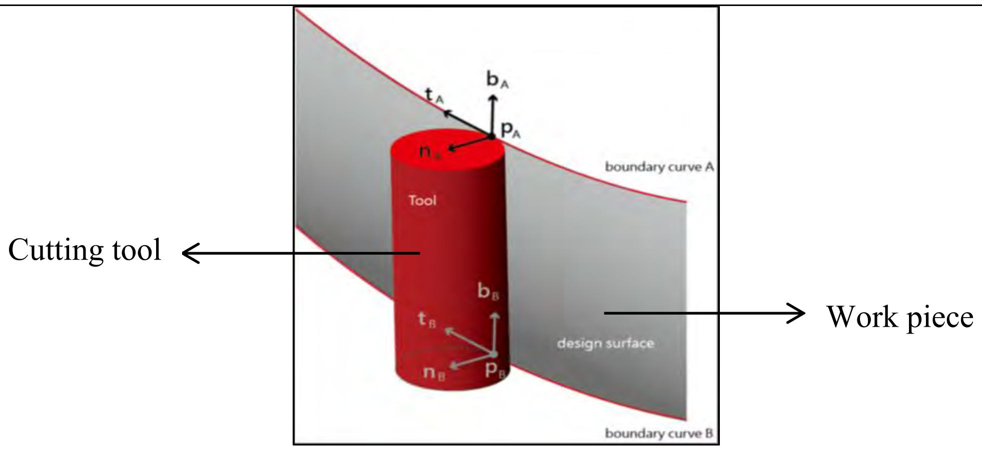


Figure 1.1: Mechanism of cutting tool in flank contouring.
(Chi-Lung Kuo., 2015)

The finish machining work piece will undergo the dimensional and surface finish analysis process. Two types of accuracy in manufacturing can be distinguished which is dimensional accuracy and shape accuracy. Dimensional accuracy is achieved when the final product falls within the tolerance bands for each dimension specified on the drawings. Increasing demand for performance designs todays, aerospace components having complex geometries and surfaces are required to be manufactured in tight tolerances. Thus, in this research the products will be undergoing the dimensional accuracy test by using a CMM machine. The testing will be done by comparing the dimensional accuracy between Combin Tanto, Tanto Fan, and Combin Parelm sample.

Surface finish or also known as surface texture or surface topography is the nature of a surface as defined by the 3 characteristic which is surface roughness, waviness and lay. Surface roughness commonly shortened to roughness, is a measure of the finely spaced surface irregularities. In engineering, this is what is usually meant by "surface finish". Meanwhile, lay is the direction of the predominant surface pattern ordinarily determined by the production method used. Lastly, waviness is the measure of surface irregularities with spacing greater than that of surface roughness. These usually occur due to warping, vibrations, or deflection during machining.

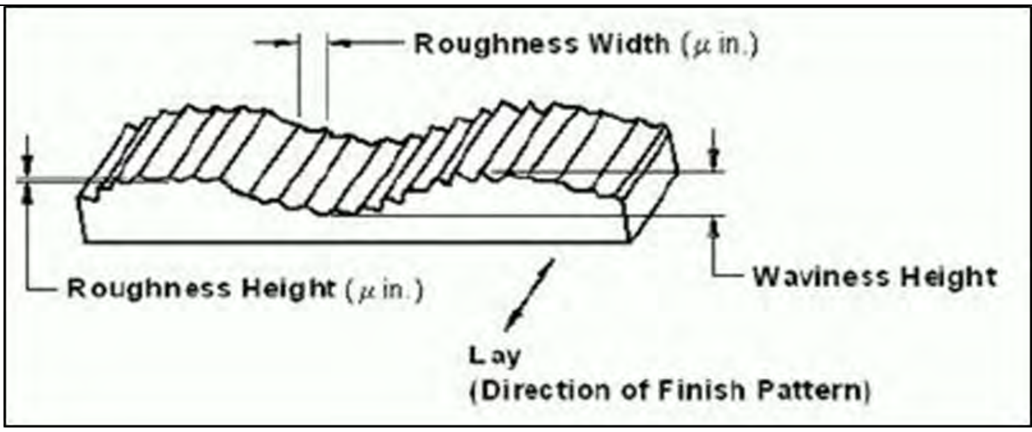


Figure 1.2: : Surface finish characteristics.
T.V, V. (1990)

There are two classes of polygons, which is convex and concave. In a convex polygon, no diagonal goes outside the figure as it travels from one corner to the other. Another property of convex polygons is that no angle inside the polygon will have a measure greater than 180 degrees. Meanwhile, Concave curve describes and inward curve while convex curve in opposites means a curve that bulges outward. They are used to describe gentle, subtle curves like the kinds found in mirrors or lenses. In mathematics, a convex function is the positive of a concave function. A convex function is also synonymously called convex downward, convex down, concave upwards, concave cap or upper concave.

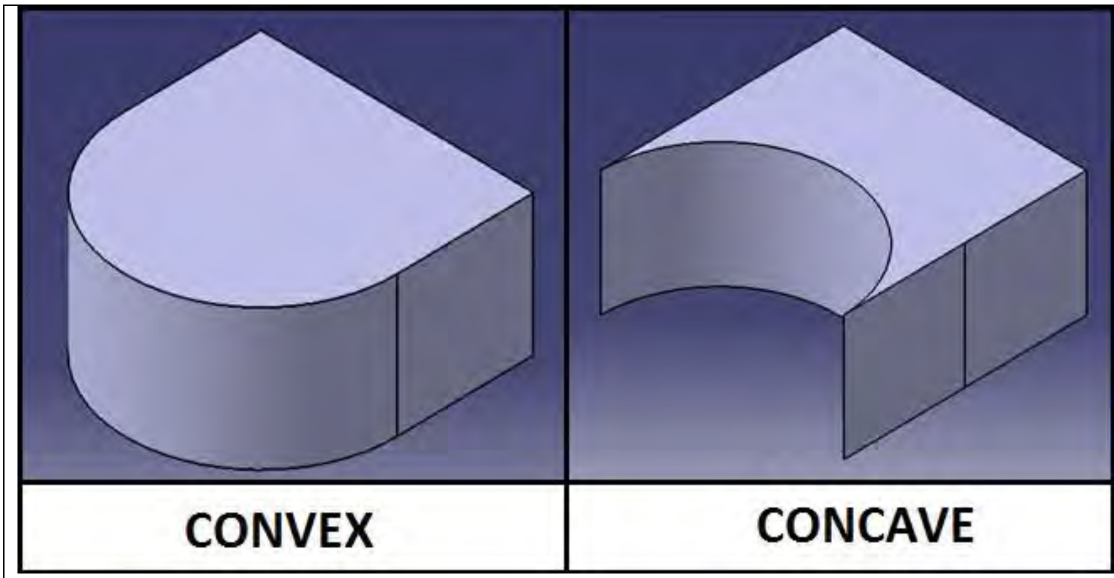


Figure 1.3: Differences between Concave and Convex curve shape

## 1.1 Problem Statement

Nowadays, products designed in aerospace industries are becoming more and more complex and complicated to meet the increasing demand of customers. Due to strong requirement from this industry, this research is utilized 5-Axis machining which offers several advantages over the traditional 3-axis machining in producing complex shape surfaces, reduces the machining time and improves the surface finish.

Most work so far has focused on point milling with end-milling of doubly curved surfaces. While much attention has been focused on machining with the bottom end of cutters (D. Dragomatz, 1997), less research has been done on a flank milling, which can provide large productivity gains for such class of surfaces as are found in blades, fans, turbines and other engineering objects (J.-M. Redonnet, 1998). Rather than milling with the tip of the tool, flank milling cuts with the shaft of the tool, removing greater amounts of material in a single pass. Flank milling is useful for machining objects such as impellers, blisks, and turbine blades, where accuracy is important. With flank milling the surface can be cut with a single pass, which is more efficient than point milling methods.

Next, common industry needs to do several test cuts in order to produce good finished product. The reason is the industry need to determine the best parameters such as tool axis for flank milling. The tool axis option named Combin Tanto, Tanto Fan, and Combin Parelm has a small contrast between each other. This small contrast between tool axis confusing the programmer to match the flank shape with the tool axis options. Moreover, this will lead to high production cost and take several times. Therefore, it is essential to study on machining strategies for flank contouring in order to know exactly the most suitable strategy for flank contouring parts.

## 1.2 Objectives

The objectives of this research are as follows:

(a) To investigate the effect on surface finish and dimensional accuracy based on machining strategies.
(b) To study the surface machining strategies (Tanto Fan, Combined Tanto, and Combined Parallelism) in producing flank shape.
(c) To make recommendations on the best machining strategy for flank at convex curve shape.

## 1.3 Scope of Study

This study started with the finding of actual CAD model that require convex shapes of flank contouring machining. The 3D part model was gained from the internet sources or actual industrial relationship (IP). Nevertheless, the 3D part model was doing some adjustment and modification on the part because this research was only focusing on flank contouring machining. Computer aided manufacturing (CAM) was involved in this research by using CADCAM software named Catia V5 because flank contouring was an option in CAM. This research was concentrated on three types of machining strategies which were Combin Tanto, Tanto Fan, and Combin Parallelism. The parameters such as depth of cut, spindle speed and feed rate were remained constant in this study. An Aluminum A6063 was identified to be used in physical machining. Then, 5-axis CNC machine was performed the machining process based on the completed part program. Two different types of analysis were tested. The first one, the part was undergo Surface Finish tested using Mitutoyo Surf Test Machine which was focused in surface roughness. The measurement of dimensional accuracy was done by using Coordinate Measuring Machine (CMM). Curve measurement was proceeded in order to inspect the dimension of the part. The part model dimension was the reference to compare with the finish product. At this point, an analysis was made according to the objectives of this research. Besides that, the evaluation of this research was based on the final result after doing machining. This is because this research concentrating on the finish product. Lastly, the report was published for further reference or improvement in the future.

# CHAPTER 2

## LITERATURE REVIEW

### 2.0 Introduction

Literature review discussed the relevant topics and a guide for studies. This section will give part in order to get more information about machining strategies of multi-axis flank contouring and will give idea how the flank machining worked. At an early stage of the studies, some gap analysis has been carried out in order to ensure the relevance of this research. Reference books, research journals and online conference article were the main source in the thesis guides. This section will include the principle of 5-axis machining, flank machining, machining strategies, dimensional accuracy, surface finish, convex angle shape and Aluminum 6063.

### 2.1 Five-axis Machining

Five-axis machining has received much attention in both industry as well as the academic community since the early 90's. It provides a number of advantages over traditional three-axis machining, such as higher production rate and fewer setups, thus it is most suitable to the production of complex geometries like turbine blade, impeller, and other high value products. A 5-axis machine gives the cutting tool access to most features of a part without changing the machine setup, as shown in Fig. 2.1. This is commonly known as 5-sided machining (Vickers, 1989). For example, a 5-axis machine can drill holes in the sides of a part by simply rotating the part. This eliminates specialized.