INFLUENCE OF VARYING DEPTH OF CUT AND FEED RATE TO TOOL WEAR RATE AND SURFACE ROUGHNESS IN ALUMINIUM, MILD STEEL AND P20 TOOL STEEL

NADIRAH BINTI ISMAIL

A thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Manufacturing Engineering

Faculty of Manufacturing Engineering

University Malaysia Pahang

JUNE 2012

ABSTRACT

Since the phenomenon of tool life still not fully understood although many research and case study have been done before, an investigation on the tool wear rate and surface roughness value being done for three types of workpiece material which are aluminium, mild steel and P20 while cutting tool that been used is carbide coated insert. The main reason for this investigation is to study and understand the behavior of cutting tool in order to determine the tool wear rate and tool life. From this investigation, surface roughness value for each type of workpiece material, Ra also can be collected. This investigation been done by applying high speed machining (HSM) concept, which high feed rate with light depth of cut.

ABSTRAK

Fenomena jangka hayat alat pemotong masih tidak difahami sepenuhnya walaupun banyak penyelidikan dan kajian telah dilakukan sebelum ini, siasatan ke atas kadar kehausan penggunaan alat pemotong dan nilai kekasaran permukaan yang dilakukan keatas tiga jenis bahan yang berbeza iaitu aluminium, keluli lembut dan P20 manakala alat pemotong yang digunakan adalah karbida yang bersalut. Tujuan utama penyelidikan ini dilakukan adalah untuk mengkaji dan memahami sifat alat pemotong untuk menentukan kadar kahausan alat pemotong dan jangka hayat alat tersebut. Dari penyiasatan ini, nilai kekasaran permukaan bagi setiap jenis bahan kerja, Ra juga boleh dikumpulkan. Penyiasatan ini dilakukan dengan menggunakan konsep pemesinan berkelajuan tinggi (HSM), kadar suapan yang tinggi dengan kedalaman potongan yang sikit.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE PAGE	**I**
	SUPERVISOR DECLARATION	**II**
	STUDENT'S DECLARATION	**III**
	DEDICATION	**IV**
	ACKNOWLEDGEMENT	**V**
	ABSTRACT	**VI**
	ABSTRAK	**VII**
	TABLE OF CONTENTS	**VIII**
	LIST OF TABLES	**XI**
	LIST OF FIGURES	**XIII**
	LIST OF ABBREVIATIONS	**XV**
1	**INTRODUCTION**	**1**
	1.1 Project Background	1
	1.2 Problem Statement	3
	1.3 Objective	5
	1.4 Scope	5
	1.5 Significance of Research	5
2	**LITERATURE REVIEW**	**6**
	2.1 Introduction	6
	2.2 Tool Wear	7
	2.2.1 Flank Wear	9
	2.3 Surface Roughness	11

	2.4 Scanning Electron Microscope	11
3	**METHODOLOGY**	**13**
	3.1 Introduction	13
	3.2 Overall Methodology	14
	3.3 Process Involved in Project	16
	3.3.1 Material and Cutting Tool	16
	3.3.2 Machining Operation	17
	3.3.2.1 Milling Machine	17
	3.3.2.2 Catia Software	18
	3.3.3 Measuring Instruments	20
	3.3.3.1 Optical video measuring system	21
	3.3.3.2 Surface roughness tester	22
	3.3.3.3 Scanning electron Microscope (SEM)	22
4	**RESULT AND DISCUSSION**	**24**
	4.1 Aspect in Design	24
	4.2 Result and Analysis for aluminium	24
	4.2.1 The Normal Probability Graph for Surface Roughness	25
	4.2.2 Relationship between Feed Rate and Depth of Cut with Surface Roughness	26
	4.2.3 The Normal Probability Graph for Tool Wear Rate	27
	4.2.4 Relationship between Feed Rate and Depth of Cut with Tool Wear Rate	28
	4.3 Result and Analysis for mild steel	29
	4.3.1 The Normal Probability Graph for Surface Roughness	30
	4.3.2 Relationship between Feed Rate and Depth of Cut with Surface Roughness	31
	4.3.3 The Normal Probability Graph for Tool Wear Rate	33
	4.3.4 Relationship between Feed Rate and Depth of Cut with Tool Wear Rate	34

4.4 Result and Analysis for P20 35

4.4.1 The Normal Probability Graph for Surface Roughness 36

4.4.2 Relationship between Feed Rate and Depth of Cut with Surface Roughness 37

4.4.3 The Normal Probability Graph for Tool Wear Rate 39

4.4.4 Relationship between Feed Rate and Depth of Cut with Tool Wear Rate 40

4.5 Result Conclusion 41

5 CONCLUSION AND RECOMMENDATION 44

5.1 Introduction 44

5.2 Project Problems 44

5.3 Conclusion 45

5.4 Recommendations 45

REFERENCES 46

APPENDICES 47 - 53

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Creater Wear on a cemented carbide tool	2
1.2	Flank Wear on a cemented carbide tool	3
1.3	Large steps using large depth of cut and slow feed rate	4
1.4	Small steps using light depth of cut and high feed rate	4
2.1	SEM view of Flank Wear for PCBN tool	10
2.2	SEM view of Flank Wear for CBN tool	10
3.1	Flowchart of Overall Methodology	14
3.2	Semi Automatic Band Saw machine	17
3.3	Milling Machine	18
3.4	Catia Software	19
3.5	Optical Video Measuring System	21
3.6	Surface Roughness Tester	22
3.7	Scanning Electron Microscope	23
4.1	The Normal Probability Graph for Surface Roughness	25
4.2	Feed Rate and Depth of Cut vs Surface Roughness Graph	26
4.3	The Normal Probability Graph for Tool Wear Rate	27
4.4	Feed Rate and Depth of Cut vs Tool Wear Rate Graph	28
4.5	The Normal Probability Graph for Surface Roughness	30

4.6	**Feed Rate and Depth of Cut vs Surface Roughness Graph**	**31**
4.7	**The Normal Probability Graph for Tool Wear Rate**	**31**
4.8	**Feed Rate and Depth of Cut vs Tool Wear Rate Graph**	**31**
4.9	**The Normal Probability Graph for Surface Roughness**	**36**
5.0	**Feed Rate and Depth of Cut vs Surface Roughness Graph**	**37**
5.1	**The Normal Probability Graph for Tool Wear Rate**	**39**
5.2	**Feed Rate and Depth of Cut vs Tool Wear Rate Graph**	**40**

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Size for each type of workpiece material	16
3.2	Size of pocketing required	18
3.3	Cutting parameters for aluminium	19
3.4	Cutting parameters for steel	20
3.5	Cutting parameters for P20	20
4.1	Result for tool wear rate and surface roughness for aluminium	24
4.2	Cutting parameters and result for surface roughness	27
4.3	Cutting parameters and result for tool wear rate	29
4.4	Result for tool wear rate and surface roughness for mild steel	30
4.5	Cutting parameters and result for surface roughness	32
4.6	Cutting parameters and result for tool wear rate	35
4.7	Result for tool wear rate and surface roughness for aluminium	36
4.8	Cutting parameters and result for surface roughness	38

4.9	**Cutting parameters and result for tool wear rate**	**41**
5.0	**Summary of Mechanical Properties**	**42**

LIST OF ABBREVIATION

HSM	**High Speed Machining**
SEM	**Scanning Electron Microscope**
D.O.C	**Depth of Cut**
PCBN	**Polycrystalline Cubic Boron Nitride**
CBN	**Cubic Boron Nitride**
NC	**Numerical Control**
CATIA	**Computer Aided Three-dimensional Interactive Application**

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

In many manufacturing process, machining represents a large part of the cost especially when looking from the aspects of the productivity. One of the major concern in machining is tool wear and surface roughness of the machined parts. Tool wear rate is an indicator of tool life while surface roughness is an indicator for dimensional accuracy. Although tool wear will certainly occurred during machining, preferably the target is gradual tool wear. Numerous previous researches conducted had proven that cutting speed is the most significant factor in determining the tool wear rate where by using high cutting speed, the material removal rate can be increased at the same time enhancing the machining productivity. Unfortunately, in many cases, the tool wear rate increase with high cutting speed.

The nature of tool wear, unfortunately, is not yet clear enough, in spite of numerous investigations. Although various theories and assumption have been introduced to explain the wear mechanism, the complexity of the processes in the cutting zone hampers the formulation of a sound theory of cutting tool wear. Therefore, the tool life cannot be predicted from only one study but many of study being done in order to understand the behavior of tool wear mechanism, to predict when tool wear occur and the period time of tool life itself. From understanding of the physics behind the process, the important wear mechanism can be identified and able to estimate the tool life. Consequently, the life of cutting tool can be classified into two main categories which are gradual wearing of certain regions of the face and flank of the cutting tool, and abrupt tool failure.[1]

Tool wear resulting in the gradual wearing away of the cutting edge. Gradual wear is more preferred since it can leads to the longest possible use of the tool. It occurs at three principal locations on a cutting tool. Accordingly, gradual wear happen at two locations on a tool which are:

- Crater wears. Figure 1.1 shows crater wear that occur on top rake face of cemented carbide tool. Crater wear is usually avoided by selecting a cutting speed and tool material that does not have an affinity to diffusion with the work material. During crater wear progresses, the effective rake angle will become more positive as the tool cutting geometry at the cutting tip changes. This results in the decrease of cutting wedge angle and weakens the cutting edge which potentially leading to microchipping and catastrophic tool failure. [2]
- Flank wear. Figure 1.2 show flank wear that occurs on flank or side of cemented carbide tool and mostly caused by abrasion, and it is the most desired form of tool wear. Flank wear leads to loss of cutting edge, and affects the dimension and surface finish quality. Tool flank wear is found to have detrimental effects on surface finish, residual stresses, and microstructural changes in the form of a rehardened surface layer (often referred to as white layer). Therefore tool flank wear land width is often used to characterize the tool life. [2]

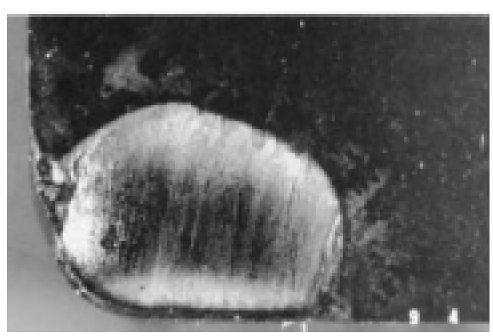

Figure 1.1: Creater Wear on a cemented carbide tool

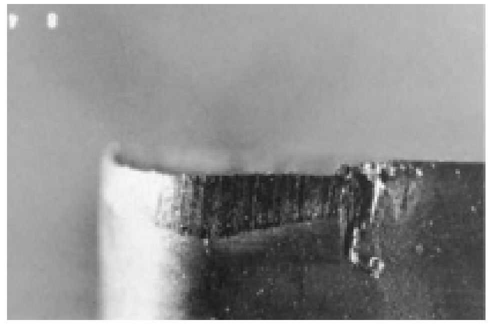

Figure 1.2: Flank Wear on a cemented carbide tool

Although cutting speed is one of important machining parameters that determine the tool wear rate, many other researches also show that cutting parameters such as axial depth of cut and feed rate cannot be neglected. In this study, varyies combination of feed rate and depth of cut are used in the investigation of tool wear rate and surface roughness while other parameters such as cutting speed, radial depth of cut and material removal rate are constant.

1.2 PROBLEM STATEMENTS

Until today, a major gap exists between the current understandings of tool wear and the ultimate goal of tool wear research. Tool wear phenomenon still not fully understood since many of investigation and vase study shown many contradictory results.While many research conducted had proven that cutting speed is the most influential machining parameters that determine the tool wear rate, the less study regarding the effect on feed rate and depth of cut to tool wear rate have been investigated.

In this study, effects of varying the combination of feed rate and depth of cut to tool wear rate and surface roughness had been acted in the milling machining starting from high depth of cut and slow feed rate until very light depth of cut and high feed rate. Cutting speed, radial depth of cut and material removal rate will be constant. The experiment had been performed by 3 axis Makino machine KE 55

The investigation done has been acted until very light depth of cut, which offer the advantages of less tool load during finishing milling process compare when using high depth of cut. Generally, two processes take place in machining which are roughing and followed by finishing process. This investigation will only consider roughing process. Another advantages using a light depth of cut is very small chips produce where less to perform cleaning rather the thick chip since high depth of cut produce large chip while light depth of cut produce small chip like particles. By using light depth of cut, semi finishing can also be eliminated since the steps occur on workpiece surface are small compare with high depth of cut.

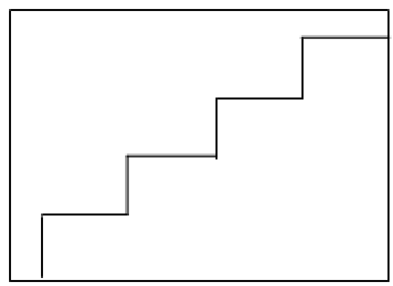

Figure 1.3: Large steps using large depth of cut and slow feed rate

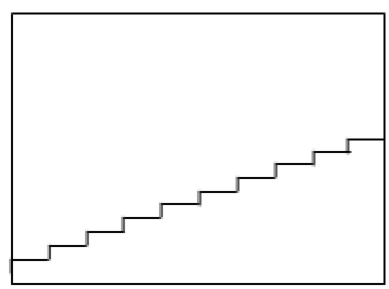

Figure 1.4: Small steps using light depth of cut and high feed rate

Figur 1.3 shows large steps that occur on workpiece surface when apply large depth of cut with slow feed rate. Since there are a large step on workpiece surface, semi finishing operation are required in order to get better and small steps on workpiece surface. Compare with figure 1.4, there are no semi finishing required since small steep occur on workpiece surface when applying light depth of cut and high feed rate.

1.3 OBJECTIVES

The objectives of this study are:

i. To investigate the effect of varying depth of cut and feed rate to tool wear rate and workpiece surface roughness during milling machining of aluminium, P20 and mild steel using constant cutting speed and material removal rate.
ii. To identify the optimum combination (feed rate and depth of cut) that will improve the tool life and workpiece surface roughness.

1.4 SCOPES

The scopes of this project are:

i. Generate CAM programming using Catia software.
ii. Investigate tool wear rate by using optical video measuring system and scanning electron microscope (SEM)
iii. Measure the surface roughness of workpiece material using surface roughness tester

1.5 SIGNIFICANCE OF RESEARCH

From this research, the benefits that could probably gain are:

i. Initiate further research to understand the tool wear behavior.
ii. Imitate other research regarding machining impact to environmental impact such as dry machining, power consumption and tool recyclability

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this section, a literature review on this research been done in order to gain through information and knowledge for the accomplishment of objectives of this project. A lot of related information had been gathered from previous study such as types of tool wear, surface roughness, scanning electron microscope (SEM), CNC milling machine, high speed machine and cutting parameters which may help during conducting the experiments in order to get the outcomes or expected result. All the information was found in article, journal, website and etc. From the literature review and on the previous study research, we can see that cutting parameters such as depth of cut, feed rate, cutting speed and tool diameter give more effect and influence to the tool life and workpiece surface itself.

There are also variable types of workpiece material such as aluminium, P20 and mild steel. Each of them has their own characteristics of material properties that can give effect to the tool life and surface roughness of workpiece material. Same goes with type of cutting tool which also have variable types of it in current market nowadays and have their own capabilities during cutting operation.

2.2 TOOL WEAR

Cutting tools are subjected to an extremely severe rubbing process. They are in metal-to-metal contact between the chip and workpiece, under conditions of very high stress at high temperature. The situation is further aggravated (worsened) due to the existence of extreme stress and temperature gradients near the surface of the tool. During machining, cutting tools remove material from the component to achieve the required shape, dimension and surface roughness (finish). However, wear occurs during the cutting action, and it will ultimately result in the failure of the cutting tool. When the tool wear reaches a certain extent, the tool or active edge has to be replaced to guarantee the desired cutting action.

Tool wear means that the change of shape of the tool from its original shape, during cutting, resulting from the gradual loss of tool material (Australian Standard, appendix B P35). Since tool wear play an important role to the period of tool life, many research been done to study and understand the behavior of tool wear and the influential of cutting parameters to the tool wear rate.

Jemielniak K (1999) stated that tool wear is an important aspect to be studied in machining operations. Importance of tool wear monitoring has been brought out by a number of researchers [3, 4]. He also reported that cutting force measurement is one of the most commonly employed methods for online tool wear monitoring, because cutting force values are most sensitive to tool wear than other measurements such as vibration or acoustic emission. While Haber et al. [5] have investigated tool wear in high-speed machining process. Their investigations with new and worn-out milling tools show that the mean and peak values of cutting force and the vibration signal exhibit the best performance for tool-condition monitoring, whereas neither the mean nor peak values of AE signal reveals a clear transition from new to worn tool.

Tool wears are complex phenomenon. S.Thamizhmanii* and S.Hasan (2010) has done study on the relationship between flank wear and cutting force on the machining of hard martensitic stainless steel by super hard tools. From the research that they have been done, the result shows that the performances of cutting tools were evaluated based on the flank wear and cutting forces. Lower cutting forces leads to low flank wear and low cutting force provides good dimensional accuracy of the work material including low surface roughness. Flank wear formation was mostly caused by abrasion and less by adhesion. The built up edge formed reduced the cutting forces. High cutting forces are identified and this may be due to heat and flank wear combinations. Flank and crater wear on the rake face and hard metal deposition due to diffusion of metals on the cutting tool surface are the damages occurred during process. According to the journal of achievement in materials and manufacturing engineering, they also have done the research on the measurement of surface roughness and flank wear on hard martensitic stainless steel by CBN and PCBN cutting tools in 2008. Tool wear is common in all the machining processes and depend on the hardness of the work materials, type of tool, rigidity of the machine, heat, formation of chips and cutting parameters [6]. All these factors also contribute to the values of the cutting forces. Cutting forces, tool wear, surface roughness and temperature induced by the cutting process and work material are the major causes of error in hard turning.

Based on Investigation of Surface Roughness and Flank Wear by CBN and PCBN Tools on Hard Cr-Mo Steel (2009) by S.Thamizhmanii* and S.Hasan, tool wear is common in all the machining process and depend on the hardness of the work pieces, type of tool, rigidity of the machine tools, generation of heat, formation of chips and cutting parameters. Tool wear, cutting forces, surface roughness and temperature induced by the cutting process by the cutting tool and work piece are the major error drive factors in hard turning [7].

One of the journal study on the tool wear of carbide as a cutting material during milling operation of gray iron and compacted graphite iron since cast iron is used widely in manufacture engine blocks and heads because of its mechanical physical properties. The main objective of the investigation is to verify the influence of the workpiece material and the cutting conditions on tool life and tool wear mechanism. The result shown that tool wear mechanism start when there are friction between the rake face and the chip and these can cause interact extensively with tool materials during machining that involves extensive plastic deformation ahead of the tool in a narrow chip zone. On mean time, the problem of stopping the machine for tool change also can be reduce and contributes to a better understanding of wear mechanisms of cutting tools used in milling operation of alloyed gray cast iron and compacted graphite iron using high cutting speed. The main conclusion from this investigation was that the material of workpiece strongly influences tool life and tool wear involves different mechanism. Abrasion and adhesion that occur at the end of tool are an example of wear mechanisms observed on the rake face. Adhesion was the main wear mechanism at higher cutting speeds

Journal on wear behaviour of cemented carbide tools in dry machining of aluminium alloy in 2005 stated that wear mechanisms involve the activation of the chemical and diffusional phenomenon. In this investigation, the researcher try to find the causes of tool wear in dry machining of aluminium alloy with cemented carbide insert. The researcher have the same opinion with S.Thamizhmanii* and S.Hasan in which the effect of tool wear may cause the formation of built-up-edge (BUE), adhesive layer on the tool rake face, the shape and efficiency of cutting tool and lastly, the surface quality and dimensional accuracy of finished product.[8]

2.2.1 Flank Wear

Generally speaking, flank wear was caused by friction between the flank face of the tool and the machined surfaces. Tool wear depends on the tool, work piece material (physical, mechanical and chemical properties), tool geometry, cutting parameters, cutting fluid, etc [6]. Flank wear generally attributed to rubbing of the tool with work piece at the interface, causing abrasive or adhesive wear and at high temperatures. Abrasion is the main wear mechanism in flank wear.

Tool flank wear was strongly influenced by the interactions between cutting tool and work piece in the form of contact stress and cutting temperature [9]. As the cutting speeds and feed rates are increased, the rubbing action also faster and more heat produced even though less contact time exist.. The generation of heat at flank side softens the edge and more wear occurred. The increase in cutting speeds wears the tool faster and reduces the life of the tool [9]

It was clear indication that the flank wears low at low cutting speed and feed rate. As the cutting speed with feed rate was increased low flank wear was observed for both the tools. In all the tests, the tool temperature increased with the cutting length and it was seen as red hot at tool tip and work piece contact point. When the tools were used for subsequent trails, the temperature increased due to increased tool flank wear. The ridges and grooves were formed on the flank side due to mechanical plowing occurred and material adhered on the flank side.

Figure 2.1 below shown the scanning electron microscope (SEM) view on flank wear for PCBN cutting tool while figure 2.2 also shown the SEM view on flank wear but different cutting tool which is CBN tool. Both figures prove that increases of cutting speed and feed rate may reduces the life of cutting tool

Figure 2.1: SEM view of Flank Wear for PCBN tool

Figure 2.2: SEM view of Flank Wear for CBN tool

2.3 SURFACE ROUGHNESS

Surface finish in turning has been found to be influenced by a number of factors such as cutting speed, cutting depth, tool nose radius, work hardness, feed rate, and cutting edge angles [8].

Surface finish is directly influenced by cutting parameters, and proper selection of cutting parameters results in high quality parts and greater savings in production time and production cost. Literature shows that a number of attempts have been made to study surface finish obtained in endmilling. Ryu et al. [10] analyzed roughness and texture generation on end-milled surfaces. Their results show that deflection increases the RMS deviation and decreases the skewness and kurtosis. This study contributes to effective cutter design, optimal cutting condition selection, and tool path generation for the reduction of machining and manual finishing time especially in precision die and mold industry. The surface finish obtained in high-speed end-milling of Al–Cu alloy has been modeled and differential evolution (DE) has been used for selection of cutting parameters [10]. However, this model is valid only when the tools are fresh as the surface topography is affected by the tool condition. Zhang et al. [8] have applied Taguchi optimization methods to optimize surface roughness value (Ra) in terms of cutting parameters for milling. The cutting parameters have been optimized for surface finish by integrating response surface methodology (RSM) with evolutionary algorithms for end-milling [10].

2.4 SCANNING ELECTRON MICROSCOPE

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. In most applications, data are collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displays spatial variations in these properties. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to 100 nm). The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD). The design and function of the SEM is very similar to the EPMA and considerable overlap in capabilities exists between the two instruments.[11]

Use of scanning electron microscope for the surface roughness measurement was successful investigated by higher resolution and by two dimensional measurement. Development of a high speed measurement system of surface roughness and that of Schmälz method to two dimensional measurement stimulated to overcome limit of the resolution due to wave length of the light source. Direct application of the scanning electron microscope (SEM) to measurement of the surface roughness has not been successful in spite of its potential to high resolution. In this investigation it was found through the observation of a standard test piece with cross section of triangular shape surface that the cross section for the electron beam scanning can be obtained by Integrating the signal which makes the image of the backscattered electrons. This characteristic was also calibrated by that the signal intensity is proportion to the inclination of the surface. It was also verified that use of symmetrically located two probes detecting the backscattered electrons assures wider range of Linear correlation between the inclination and the intensity of the backscattered electrons. The operational amplifier for the integral was especially equipped with the SEM, which made it possible to obtain two dimensional surface roughness by performing the integral for the respective scannings. Applications of this method to the surface of the test piece above mentioned, of an integrated electronic circuit, and of ground area was successful to show the results on CPT display. Measurement of elaborately attached surface with wave length of 2.55um showed that order of 2.001 μm max is possible as the resolution by magnification of 90,000.[12]

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this section, detail explanation on the methodology of carrying out this project from the beginning to the end had been carried out. The main objectives by doing this methodology to see the flow of the project and the process that involve during do this research. Title was given by the supervisor in the beginning of this semester including objectives and scopes of the project. Since the title is "Influential of varying depth of cut and feed rate to tool wear rate and workpiece surface roughness for three differences materials", a detail related literature review was done and important information were acquired and explained in previous chapter. The previous studies and investigations in journals, articles and others sources that relate with the tool wear phenomenon and surface finish of workpiece will help to conduct during the investigation being done. 3D drawing was done by using CATIA software in order to get the machining time from simulation video and generate NC code as a program that been transfer to the milling machine as a command for the machine to do the machining. The study was carried out by simultaneously varying of cutting parameters (feed rate and depth of cut) and data from the experiments been collected by using optical video measuring system and surface roughness tester.