PERFORMANCE OF COATED AND UNCOATED CARBIDE TOOLS WHILE DRY MACHINING ALUMINIUM ALLOY

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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For my beloved Family Members,

Especially my Parents

And unforgettable all my friends…

May Allah bless you...!!

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In the name of Allah, the Most Beneficent, the Most Merciful. First of all I am very grateful to the One and Mighty Creator, for giving me strength to complete this project successfully. It is only through His mercy that this project could be complete. Perhaps this project Praise is to God.

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ABSTRACT

Coated and uncoated carbide tools are widely use in metal working industry. This study is to investigate the performance of coated and uncoated carbide tool while dry machining 6061 aluminium alloy in term of surface roughness. There are many factors that affect the performance of cutting tool especially when dry machining. Nowadays, there are many type of cutting tools invented by manufacture engineers to overcome the problem. As an example the coated and uncoated carbide cutting tools. This two cutting tools have their advantages and disadvantages. We try to investigate the best cutting tool whether coated or uncoated carbide cutting tool for dry machining Aluminium Alloy. Response surface methodology (RSM) was use for the analysis of the surface roughness. From this research, the result show the coated carbide tool has better surface roughness than uncoated carbide tool. The surface roughness of coated tool carbide tool can be fine when the cutting speed is 200m/min, depth of cut is 0.5mm and feed is 0.02mm/tooth. The surface roughness of uncoated tool carbide can be fine when the cutting speed is 240m/min, depth of cut is 0.5mm and feed is 0.06mm/tooth.The coated carbide tool is the most suitable in machining aluminium alloy compare to uncoated carbide tool.

ABSTRAK

Dalam proses pemotongan alat pemotong amat penting. Alat pemotong hendaklah sesuai dengan bahan yang ingin dipotong. Kajian ini adalah untuk mengetahui kemampuan alat pemotong kalsium karbida bersalut dan alat pemotong kalsium karbida tidak bersalut dalam pemotongan kering 6061 aluminium aloi. Terdapat banyak sebab yang mempengaruhi kemampuan pemotongan terutamanya dalam pemotongan kering. Harini, terdapat banyak alat pemotong telah dicipta bagi menangani masalah pemotongan sebagai contoh alat pemotong kalsium karbida bersalut. Dua alat pemotong ini memiliki kelebihan dan kekurangan. Penyiasatan dibuat untuk menyiasat alat pemotong terbaik apakah karbida bersalut atau tidak bersalut pahat untuk mesin kering Aluminium Alloy. Dalam menyiasat tujuan, metodologi permukaan rawak (RSM) adalah memilih menentukan kekasaran permukaan. Dari kajian ini, hasilnya menunjukkan alat karbida bersalut mempunyai kekasaran permukaan yang lebih baik dari alat karbida tidak bersalut. Kekasaran permukaan dilapisi alat pemotong karbida boleh halus ketika kelajuan potong 200m/min, kedalaman potong adalah 0.5mm danpakan 0.02mm/gigi.

TABLE OF CONTENTS

		Page
SUPERVISOR'S DECLARATION		ii
STUDENT'S DECLARATION		iii
DEDICATION		iv
ACKNOWLEDGEMENTS		v
ABSTRACT		v
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xi
LIST OF FIGURES		xii
LIST OF SYMBOLS		xiv
LIST OF ABBREVIATIONS		xv
CHAPTER 1	**INTRODUCTION**	
1.1	Background of Study	1
1.2	Problem Statement	2
1.3	Objectives of Study	2
1.4	Scopes of Project	3
CHAPTER 2	**LITERATURE REVIEW**	
2.1	Introduction	4
2.2	Dry machining	4
2.3	Milling Machine	6
2.4	Cutting Tool	9
	2.4.1 Carbides (uncoated tools)	9
	2.4.2 Coated Carbides (coated tools)	10
2.5	Aluminium Alloy	11
2.6	Surface Roughness	12

CHAPTER 3 METHODOLOGY

3.1 Introduction 14

3.2 Design Of Experiment 15

3.2.1 Work Piece Material 16

3.2.2 Cutting Tool Geometry 17

3.4 Experiment Technique 17

CHAPTER 4 RESULT AND DISCUSSIONS

4.1 Introduction 18

4.2 Experiment Analysis Result 18

4.3 Response Surface Methodology 20

4.3.1 Estimated Regression Coefficient of Ra 21

4.3.2 Analysis of Variance for Ra 21

4.4 Comparison of the Coated and Uncoated Carbide Tools in Surface Roughness 33

CHAPTER 5CONCLUSION AND RECOMMENDATION

5.1 Conclusions 35

5.2 Recommendations 36

REFERENCES 37

APPENDICES

A1 Graphs for low level. (Coated carbide tool) 38

Figure 6.1 contour plot: depth of cut Vs Cutting Speed 38

Figure 6.2 contour plot: Feed Vs Cutting Speed 39

Figure 6.3 contour plot: Feed Vs Depth of Cut 39

Figure 6.4 surface plot: Ra Vs Cutting Speed, Depth of Cut 40

Figure 6.5 surface plot: Ra Vs Cutting Speed Vs Feed 40

Figure 6.6 surface plot: Ra Vs Depth of Cut, Feed 41

A2	Graphs for high level. (Coated carbide tool)	42
	Figure 6.7 contour plot: depth of cut Vs Cutting Speed	42
	Figure 6.8 contour plot: Feed Vs Cutting Speed	43
	Figure 6.9 contour plot: Feed Vs Depth of Cut	43
	Figure 6.10 surface plot: Ra Vs Cutting Speed, Depth of Cut	44
	Figure 6.11 surface plot: Ra Vs Cutting Speed Vs Feed	44
A3	Graphs of low level (uncoated carbide tool)	45
	Figure 6.12 Contour plot: Depth of cut vs. cutting speed	45
	Figure 6.13 Contour plot: Feed vs. cutting speed	46
	Figure 6.14 Contour plot: Feed vs. depth of cut	46
	Figure 6.15 Surface plot: Ra vs. cutting speed, depth of cut	47
	Figure 6.16 Surface plot: Ra vs. depth of cut, feed	47
	Figure 6.17 Surface plot: Ra vs. cutting speed, feed	48
A4	Graphs of high level. (Uncoated carbide tool)	49
	Figure 6.18 Contour plot: depth of cut vs. cutting speed	49
	Figure 6.19 Contour plot: Feed vs. cutting speed	50
	Figure 6.20 Contour plot: Feed vs. depth of cut	50
	Figure 6.21 Surface plot: Ra vs. cutting speed, depth of cut	51
	Figure 6.22 Surface plot: Ra vs. depth of cut, feed	51
	Figure 6.23 Surface plot: Ra vs. cutting speed, feed	52
B1	Gantt chart / project schedule for fyp 1	53
B2	Gantt chart / project schedule for fyp 2	54

LIST OF TABLES

Table No.	Title	Page
3.1	Data that we got from Minitab software	16
4.1	Coated carbideL^t : 17.5 mm	19
4.2	Uncoated carbideL^t : 17.5 mm	19
4.3	Estimated Regression Coefficients for Ra (coated tools)	20
4.4	Estimated Regression Coefficient for Ra (uncoated tools)	21
4.5	Analysis of Variance for Ra (coated tool)	21
4.6	Analysis of Variance for Ra (uncoated tool)	22

LIST OF FIGURES

Figure No.	Title	Page
4.1	Contour plot: Depth of Cut Vs Cutting Speed. (medium level)	22
4.2	Contour plot: Feed vs. Cutting Speed	23
4.3	Contour plot: Feed vs. Depth of Cut	24
4.4	Surface plot: Ra vs. Depth of Cut, Cutting Speed	25
4.5	Surface plot: Ra vs. Cutting Speed, Feed	26
4.6	Surface plot: Ra vs. Feed, Depth of Cut	27
4.7	Contour plot: Depth of Cut Vs Cutting Speed. (medium level)	28
4.8	Contour plot: Feed vs. Cutting Speed.	29
4.9	Contour plot: Feed vs. Depth of Cut	30
4.10	Surface plot: Ra vs. Depth of Cut, Cutting Speed	31
4.11	Surface plot: Ra vs. Cutting Speed, Feed	32
4.12	Surface plot: Ra vs. Feed, Depth of Cut	33

LIST OF SYMBOLS

V	Potential Energy or Voltage
Ω	Ohm
m	Metre
cm	Centimetre
g	gram
g/cm^3	Density
mmpy	millimetres per year
*i*corr	Corrosion current density
*E*corr	Corrosion potential
b_a	Anodic Tafel slopes
b_c	CathodicTafel slopes
%	Percentage
°C	Degree Celsius

LIST OF ABBREVIATIONS

NaCl	Sodium Chloride
Zn	Zinc
Al	Aluminium
Mg	Magnesium
Fe	Ferrum
Si	Silicon
Cu	Copper
H	Hydrogen
O	Oxygen
e^-	Electron
ASTM	American Standard Testing Method
SEM	Scanning Electron Microscope
EDS	Energy Dispersive X-Ray Spectroscopy
T	Time
A	Surface Area
W	Mass Loss in grams
D	Density

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION.

Coated and uncoated carbides are widely used in the metal-working industry and provide the best alternative for most machining operations. When machining using carbides under typical cutting conditions, the gradual wear of the flank and rake faces is the main process by which a cutting tool fails. It carried out tool wear investigations on some cutting tool materials. Plotted tool life curves using the flank wear criterion and obtained that the tool life of carbides decreased quickly at higher speed.

The flank wear in carbide tools initially occurs due to abrasion and as the wear process progresses, the temperature increases causing diffusion to take place. Actually, the fact that abrasive wear may occur in metal cutting is not surprising since there are many hard abrasive particles present in metals, especially in steel.

The use of coolant to increase tool life is an issue with many differing views. In contrast, others have found that coolant promotes tool wear in machining. The inherent brittleness of carbides renders them susceptible to severe damage by cracking if sudden loads of thermal gradients are applied to their edge . The better performance of carbides was obtained under dry cutting.

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. Nowadays, most of the carbide cutting tools are coated whether with CVD or PVD hard coatings. PVD–TiAlN-coated-carbide tools are used frequently in metal cutting process due to their high hardness, wear resistance and chemical stability they offer benefits in terms of tool life and machining performance. However, we will compare the performance of coated carbide cutting tool with uncoated carbide cutting tool (uncoated-WC/Co) while dry milling process.

1.2 PROBLEM STATEMENT

There are many factors that affect the performance of cutting tool especially when dry machining. Nowadays, there are many type of cutting tools invented by manufacture engineers to overcome the problem. As an example the coated and uncoated carbide cutting tools. This two cutting tools have their advantages and disadvantages. We try to investigate the best cutting tool whether coated or uncoated carbide cutting tool for dry machining Aluminum Alloy. Surface roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

1.3 OBJECTIVE.

The objective of this project is to investigate the performance of coated and uncoated carbide cutting tool while dry machining Aluminum Alloy in term of surface roughness.

1.4 SCOPE OF PROJECT

The identified scope of this project is as follows:-

1.4.1. Milling the Aluminum Alloy with both cutting tools (coated and uncoated) using milling machine.

1.4.2. Machining the Aluminum Alloy with various cutting speed.

1.4.3. Getting the surface roughness using perthometer.

1.4.4. Analysis data using Response Surface Methodology.

1.4.5. Review data.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A significant of this chapter is based on experimental to investigate the performance of coated and uncoated cutting when dries machining Aluminium Alloy. Basic understanding in the study must be recognizable before the experiment has been through.

2.2 DRY MACHINING.

Dry machining is ecologically desirable and it will be considered as a necessity for manufacturing enterprises in the near future. Industries will be compelled to consider dry machining to enforce environmental protection laws for occupational safety and health regulations. The advantages of dry machining include: non-pollution of the atmosphere(or water); no residue on the swarf which will be reacted in reduced disposal and cleaning costs; no danger to health; and it is non-injurious to skin and is allergy free. Moreover, it offers cost reduction in machining. (Narutaki et. al, 1997)

The various possible routes to achieve clean machining processes were analyzed and discussed by Byrne, 1996. Elimination on the use of cutting fluids, if possible, can be a significant incentive. The costs connected with the use of cutting fluids are estimated to be many more times than the labor and overhead costs. Hence the implementation of dry machining will reduce manufacturing costs. In the manufacturing industry, cutting fluids help to remove the heat generated due to friction during cutting to achieve better tool life, surface finish and dimensional tolerances to prevent the formation of built-up edge and to facilitate the transportation of chips. Coolants are essential in the machining of materials such as aluminium alloys and most stainless steels, which tend to adhere to the tool and cause a built-up edge. At the same time, the coolants produce problems in the working environment and also create problems in waste disposal. This creates a large number of ecological problems, but which in turn result in more economical overheads for manufacturing industries. If industries were to practice dry machining, then all of the above-mentioned problems should be addressed satisfactorily. The cutting fluid industries are reformulating new composites that are more environmental friendly and which do not contain Pb, S or Cl compounds. (Santhanakrishnan, 1994)

Consumption of cutting fluids has been reduced considerably by using mist lubrication. However, mist in the industrial environment can have serious respiratory effects on the operator. The use of cutting fluids will be increasingly more expensive as stricter enforcement of new regulation and standards are imposed, leaving no alternative but to consider dry machining. Many metal-cutting processes have been developed and improved based on the availability of coolants. It is well known that coolants improve the tool life and tool performance to a great extent. In dry machining, there will be more friction and adhesion between the tool and the work piece, since they will be subjected to higher temperatures.

This will result in increased tool wear and hence reduction in tool life. Higher machining temperatures will produce ribbon-like chips and this will affect the form and dimensional accuracy of the machined surface. However, dry cutting also has some positive effects, such as reduction in thermal shock and hence improved tool life in an interrupted-cutting environment. (Sreejith and Ngoi, 1999)

2.3 MILING MACHINE.

A milling machine is a machine tool used to machine solid materials. Milling machines exist in two basic forms: horizontal and vertical, which terms refer to the orientation of the cutting tool spindle. Unlike a drill press, in which the work piece is held stationary and the drill is moved vertically to penetrate the material, milling also involves movement of the work piece against the rotating cutter, the latter of which is able to cut on its flanks as well as its tip. Work piece and cutter movement are precisely controlled to less than 0.001 in (0.025 mm), usually by means of precision ground slides and lead screws or analogous technology. Milling machines may be manually operated, mechanically automated, or digitally automated via computer numerical control (CNC). Milling machines can perform a vast number of operations, some very complex, such as slot and keyway cutting, planning, drilling, die sinking, rebating, routing, etc. Cutting fluid is often pumped to the cutting site to cool and lubricate the cut, and to sluice away the resulting swarf.

There are many ways to classify milling machines, depending on which criteria are the focus:

Criterion	Example classification scheme	Comments
Control	Manual; Mechanically automated via cams; Digitally automated via NC/CNC	In the CNC era, a very basic distinction is manual versus CNC. Among manual machines, a worthwhile distinction is non-DRO-equipped versus DRO-equipped
Control (specifically among CNC machines)	Number of axes (e.g., 3-axis, 4-axis, or more); Within this scheme, also: Pallet-changing versus	

	non-pallet-changing ▪ Full-auto tool-changing versus semi-auto or manual tool-changing	
Spindle axis orientation	Vertical versus horizontal; Turret versus non-turret	Among vertical mills, "Bridgeport-style" is a whole class of mills inspired by the Bridgeport original
Purpose	General-purpose versus special-purpose or single-purpose	
Purpose	Toolroom machine versus production machine	Overlaps with above
Purpose	"Plain" versus "universal"	A distinction whose meaning evolved over decades as technology progressed, and overlaps with other purpose classifications above; more historical interest than current
Size	Micro, mini, bench top, standing on floor, large, very large, gigantic	
Power source	Line-shaft-drive versus individual electric motor drive	Most line-shaft-drive machines, ubiquitous circa 1880-1930, have been scrapped by now
	Hand-crank-power versus electric	Hand-cranked not used in industry but suitable for hobbyist micro mills

Figure 2.1 CNC machine criteria

Most CNC milling machines (also called machining centers) are computer controlled vertical mills with the ability to move the spindle vertically along the Z-axis. This extra degree of freedom permits their use in die sinking, engraving applications, and 2.5D surfaces such as relief sculptures. When combined with the use of conical tools or a ball nose cutter, it also significantly improves milling precision without impacting speed, providing a cost-efficient alternative to most flat-surface hand-engraving work.

Figure 2.2 CNC Milling Machine.

CNC machines as shown in figure 2.2 can exist in virtually any of the forms of manual machinery, like horizontal mills. The most advanced CNC milling-machines, the multi axis machine, add two more axes in addition to the three normal axes (XYZ). Horizontal milling machines also have a C or Q axis, allowing the horizontally mounted work piece to be rotated, essentially allowing asymmetric and eccentric turning. The fifth axis (B axis) controls the tilt of the tool itself. When all of these axes are used in conjunction with each other, extremely complicated geometries, even organic geometries such as a human head can be made with relative ease with these machines. But the skill to program such geometries is beyond that of most operators. Therefore, 5-axis milling machines are practically always programmed with CAM. With the declining price of computers, free operating systems such as Linux, and open source CNC software, the entry price of CNC machines has plummeted. (Kurimoto and Barrow, 1982)

2.4 CUTTING TOOLS.

The selection of cutting tool materials for a particular application is among the most important factors in machining operations, as is the selection of mold and die material for forming and shaping process. The cutting tool is subjected to high temperatures, high contact stress, and rubbing along the tool chip interface and along the machined surface. Consequently, the cutting tool material must possess the following characteristic like hot hardness, toughness and impact strength, thermal shock resistance, wear resistance, and chemical stability and inertness.

2.4.1 Carbides (uncoated tool)

To meet challenge for increase higher cutting speeds, carbides (also known as cemented or sintered carbides) were introduced in the 1930s. Because of their high hardness over a wide range of temperature, high elastic modulus, high thermal conductivity, and low thermal expansion, carbide are among the most important, versatile, and cost effective tool and die materials for a wide range of application. The two types of major carbide used for machining are tungsten carbide and titanium carbide. This two also referred to as uncoated carbide. (Che Haron et. al, 2001)

Tungsten carbide (WC) typically consists of tungsten carbide particles bonded together in a cobalt matrix. The tools are manufactured using powder metallurgy technique (hence the term sintered carbide and cemented carbide). The tungsten carbide particles are first combined with cobalt in a mixer, resulting in a composite material with a cobalt matrix surrounding the carbide particles. These particles, which are 1 to 5 µm in size, are then pressed and sintered into the desires, insert shapes. Tungsten carbides frequently are compounded with titanium carbide and niobium carbide to impart special properties to the material.

The amount of cobalt present, ranging typically from 6 to 16%, significantly affects the properties of tungsten carbide tools. As the cobalt increases, the strength, hardness, and wear resistance of WC decrease whiles its toughness increase because of the higher toughness of cobalt. Tungsten carbide tools generally are used for cutting steel, casts iron, and abrasives nonferrous material and largely have replace HSS tools because of their better performance.

2.4.2 Coated carbide (coated tool)

New alloy and engineered material are being developed continuously, particularly since 1960s. These materials have high strength and toughness but generally abrasive and chemically reactive with tool materials. The difficulty of machining these material efficiently and the need for improving the performance in machining the more common engineering material have led to important development in coated tools. Coating have unique properties, such as lower friction, higher adhesion, higher resistance to wear and cracking, acting as diffusion barrier and higher hot hardness and impact resistance.

Coated tools can have tool lives 10 times longer than those of uncoated tools, allowing for high cutting speeds and thus reducing both the time required for machining operation and production costs. This improvement had a major impact on the economics of machining operation in conjunction with continued improvement in the design and construction of modern machine tools and their computer controls. As a result, coted tools now are used in 40 to 80% of all machining operation, particularly in turning, milling and drilling. Survey has indicated that the use of coated tools is more prevalent in larger companies than in smaller one. (Jayaram et. al, 1995)

Commonly used coating materials are titanium nitride (TiN), titanium carbide (TiC), Titanium carbonitride (TiCN) and aluminum oxide. These coating, generally in the thickness range of 2 to 15µm, applied on cutting tools and inserts by two techniques, chemical vapor deposition(CVD) and physical vapor deposition(PVD). Titanium carbide coatings on tungsten carbide insert have high flank wear resistance in machining abrasive material.

2.5 Aluminum Alloy

Aluminum alloys are alloys in which aluminum is the predominant metal. Typical alloying elements are copper, zinc, manganese, silicon, and magnesium. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminum is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminum alloys yield cost effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys.

The most important cast aluminum alloy system is Al-Si, where the high levels of silicon (4-13%) contribute to give good casting characteristics. Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required, I. J. Polymer, Light Alloys, Arnold, 1995.Aluminium alloy surfaces will keep their apparent shine in a dry environment due to the formation of a clear, protective oxide layer. In a wet environment, galvanic corrosion can occur when an aluminum alloy is placed in electrical contact with other metals with a more negative corrosion potential than aluminum.

Aluminum alloy compositions are registered with The Aluminum Association. Many organizations publish more specific standards for the manufacture of aluminum alloy, including the Society of Automotive Engineers standards organization, specifically its aerospace standards subgroups, SAE aluminum specifications list, accessed Oct 8, 2006. Also SAE Aerospace Council, accessed Oct 8, 2006 and ASTM International. (Sreejith and Sreejith, 2007)

2.6 Surface Roughness

Surface roughness, often shortened to roughness, is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

A roughness value can either be calculated on a profile or on a surface. The profile roughness parameter (Ra, Rq,...) are more common. The areal roughness parameters (Sa, Sq,...) give more significant values. Each of the roughness parameters is calculated using a formula for describing the surface. There are many different roughness parameters in use, but Ra is by far the most common. Other common parameters include Rz, Rq, and Rsk. Some parameters are used only in certain industries or within certain countries. For example, the Rk family of parameters is used mainly for cylinder bore linings, and the Motif parameters are used primarily within France. (Sharif and Rahim. 2007.)

Since these parameters reduce all of the information in a profile to a single number, great care must be taken in applying and interpreting them. Small changes in how the raw profile data is filtered, how the mean line is calculated, and the physics of the measurement can greatly affect the calculated parameter. By convention every 2D roughness parameter is a capital R followed by additional characters in the subscript. The subscript identifies the formula that was used, and the R means that the formula was applied to a 2D roughness profile.

Different capital letters imply that the formula was applied to a different profile. For example, Ra is the arithmetic average of the roughness profile, Pa is the arithmetic average of the unfiltered raw profile, and Sa is the arithmetic average of the 3D roughness. Roughness is often closely related to the friction and wear properties of a surface. A surface with a large Ra value, or a positive Rsk, will usually have high friction and wear quickly. The peaks in the roughness profile are not always the points of contact. The form and waviness must also be considered.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will further describe the study of performance of coated and uncoated carbide cutting tools while dry machining aluminum alloy. An experiment will be set up in order to complete this project. Methodology is one of the most important parts to be considered to ensure that the project run smoothly and will get expected result which is needed. In this chapter, it will discuss about the process of project due to flow chart or more specifically due to Gantt chart. In this methodology, there is several steps must be followed to make sure the objective of the project achieved start from literature finding until submit the report. Below are the steps of the project which briefly into flow chart schematic diagram.

3.2. DESIGN OF EXPERIMENT

This experiment conducted to measure the tool life, T and the cutting speed, V from the preliminary test. From experiment result an observation will be taken on the tool surface to analyze the flank wear, and rake wear, the data collected will then generated into the equation using Minitab software.

Recommend method:

RSM (response surface methodology):

1. BBD(Box-Behnken Design)
2. CCD(Central Composite Design)

The use of this method is to simplify the parameters that we can't predict the values. It will save time and cost of the experiment.

Three factors can be determined and produce enough functional relationship between factors and response. We choose RSM method. There are two type of method in RSM that is CCD and BBD. We choose BBD for this experiment. Box-Behnken Design do not have axial points, thus can be sure that all design points fall within the safe operating. The Box-Behnken Design method has been done with using Minitab software. Preliminary tests were carried out to find the suitable cutting speed, feed rate and axial depth.

Table 3.1 Minitab software data.

Run Order	Cutting Speed (m/min)	Depth of Cut (mm)	Feed (mm/tooth)
1	175	0.50	0.10
2	175	1.25	0.06
3	175	1.25	0.06
4	175	2.00	0.06
5	100	2.00	0.10
6	250	1.25	0.06
7	250	2.00	0.10
8	175	1.25	0.06
9	100	1.25	0.02
10	250	0.50	0.06
11	175	2.00	0.02
12	250	1.25	0.02

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3.2.1 Work piece material

In this study, aluminum alloy T6061 was selected as the work piece material. The material was supplied in fully annealed condition, rectangular in shape, 100 mm length, 90mm width, and 30mm thick in size. Each bar was checked for its hardness across the area cross-section of the work piece at each end prior to the tests and the average value of the hardness measurements will be measured.

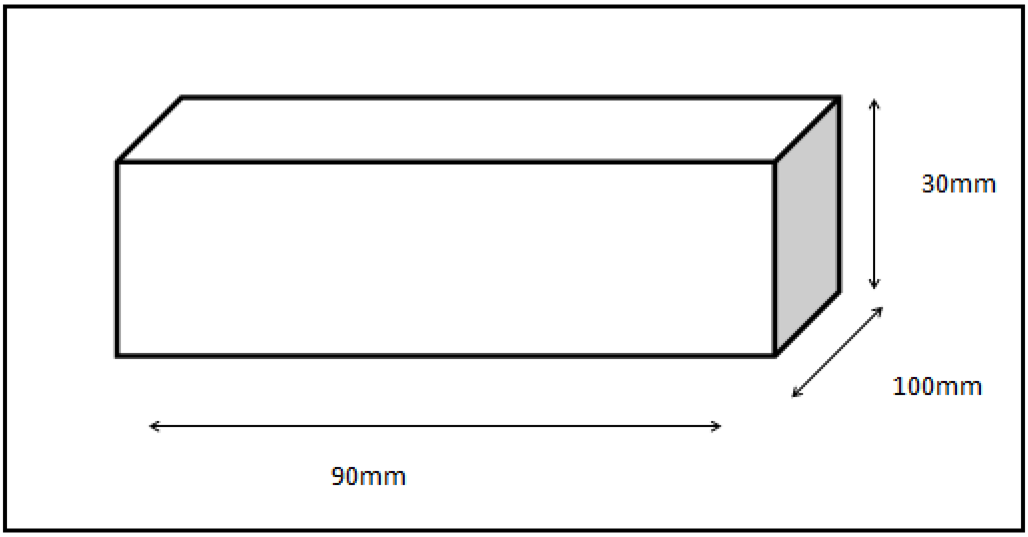

Figure 3.1 The illustration of work piece

3.2.2 Cutting tools and tool geometry

Coated and uncoated carbide inserts were used for the milling tests. For the uncoated carbide tool, there are two major groups of carbides used for machining, tungsten carbide and titanium carbide. For this experiment, we decided to choose titanium carbide for uncoated carbide cutting tool. Coated carbide tool, we use titanium carbide coatings.

3.4 EXPERIMENT TECHNIQUE

The assembled tool and work piece were mounted on a Haas CNC milling machine. The CNC milling centre was operated at the specified cutting conditions described previously. After all the cutting process done, the work piece was tested using perthometer to get is surface roughness.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, the result from the experiment and analysis will be discussed. This research is about the performance of coated and uncoated carbide tools while dry machining aluminum alloy. The research carries out using the experimental analysis using response surface methodology (RSM). The experiment was carried out according the condition as mentioned in table 3.1 to get the data result that will be used as the boundary condition in the analysis.

4.2 Experimental Analysis Result

From the experiment analysis, a set of data is collected when the work piece is milling in the several feed rate, axial depth and cutting speed. These all data will be used in analyzing the surface roughness of the aluminum alloy. The surface roughness were checked using perthometer to get the Ra. The data result from the experimental analysis for the coated and uncoated carbide tools is shown in table 4.1 and table 4.2. These two set of data will be compare with the some simulation using Minitab software.

Table 4.1: Coated carbide L^t : 17.5 mm

Run Order	Cutting Speed (m/min)	Depth of Cut (mm)	Feed (mm/tooth)	RPM	Feed Rate (mm/min)	Ra (µm)
1	175	0.50	0.10	1114	446	0.156
2	175	1.25	0.06	1114	267	0.095
3	175	1.25	0.06	1114	267	0.142
4	175	2.00	0.06	1114	446	0.159
5	100	2.00	0.10	640	153	0.306
6	250	1.25	0.06	1591	636	0.132
7	250	2.00	0.10	1591	381	0.224
8	175	1.25	0.06	1114	267	0.173
9	100	1.25	0.02	640	51	0.100
10	250	0.50	0.06	1591	381	0.140
11	175	2.00	0.02	1114	89	0.115
12	250	1.25	0.02	1591	153	0.052

Table 4.2: Uncoated carbide L^t : 17.5 mm

Run Order	Cutting Speed (m/min)	Depth of Cut (mm)	Feed (mm/tooth)	RPM	Feed Rate (mm/min)	Ra (µm)
1	175	0.50	0.10	1114	446	0.176
2	175	1.25	0.06	1114	267	0.115
3	175	1.25	0.06	1114	267	0.148
4	175	2.00	0.06	1114	446	0.179
5	100	2.00	0.10	640	153	0.326
6	250	1.25	0.06	1591	636	0.152
7	250	2.00	0.10	1591	381	0.244
8	175	1.25	0.06	1114	267	0.193
9	100	1.25	0.02	640	51	0.120
10	250	0.50	0.06	1591	381	0.160
11	175	2.00	0.02	1114	89	0.135
12	250	1.25	0.02	1591	153	0.092

4.3 Response Surface Methodology (RSM)

Response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The method was introduced by G. E. P. Box and K. B. Wilson in 1951. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. There are three step in analyzing data using RSM, it were design of experiment, define custom response surface and analyze response surface design.

4.3.1 Estimated Regression Coefficient of Ra

The analysis was done using encoded units. In this table we need to get the R-Sq more than 70%. This is because to make sure the data that we got is close to prediction. The other is need is the any other variable must have value less than 0.05. We can eliminate the P value which is greater than 0.05. This value shows the optimum surface roughness.

Table 4.3 Estimated Regression Coefficients for Ra (coated tools)

Term	Coef	SE Coef	T	P
Constant	0.03427	0.053808	0.637	0.542
Cutting Speed (m/min)	-0.00019	0.000190	-0.996	0.348
Depth of Cut (mm)	0.04315	0.019025	2.268	0.053
Feed (mm/tooth)	1.57917	0.336927	4.687	0.002

S = 0.0330119 PRESS = 0.0234022

R-Sq = 78.72% R-Sq(pred) = 42.87% R-Sq(adj) = 70.74%

Table 4.4 Estimated Regression Coefficient for Ra (uncoated tools)

Term	**Coef**	**SE Coef**	**T**	**P**
Constant	0.05173	0.053286	0.971	0.360
Cutting Speed (m/min)	-0.00022	0.000188	-1.177	0.273
Depth of Cut (mm)	0.04372	0.018840	2.321	0.049
Feed (mm/tooth)	1.66250	0.333658	4.983	0.001

S = 0.0326917 PRESS = 0.0221128

R-Sq = 80.66% R-Sq(pred) = 49.97% R-Sq(adj) = 73.40%

4.3.2 Analysis of Variance for Ra

This analysis was carried out for a level of significance of 5% (α=0.05), for 95% a level of confidence. The parameter is significant due to P-value of lack of fit is 0.730 and 0.737 that is greater than 0.05 of the level of significant. This implies that the model can fit and it is adequate. Other than that there are several indicators to evaluate the effectiveness of the model built in the surface roughness prediction. Source indicate that the source of the variation either from factor then the total of the sum of the entire source.

Table 4.5 Analysis of Variance for Ra (coated tool)

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Regression	3	0.032245	0.032245	0.010748	9.86	0.005
Linear	3	0.032245	0.032245	0.010748	9.86	0.005
Residual Error	8	0.008718	0.008718	0.001090		
Lack of Fit	6	0.005634	0.005634	0.000939	0.61	0.730
Pure Error	2	0.003085	0.003085	0.001542		
Total	11	0.040964				

Table 4.6 Analysis of Variance for Ra (uncoated tool)

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Regression	3	0.035650	0.035650	0.011883	11.12	0.003
Linear	3	0.035650	0.035650	0.011883	11.12	0.003
Residual Error	8	0.008550	0.008550	0.001069		
Lack of Fit	6	0.005484	0.005484	0.000914	0.60	0.736
Pure Error	2	0.003066	0.003066	0.001533		
Total	11	0.044200				

All the data will be analyze using Minitab software using response methodology method (RSM). Two graphs were plotted for each type of analysis. The first is contour plot and the second one is surface plot. There are three levels of graphs that we plotted. It was low, medium and high level. We have to decide to choose a level to be compared. We choose the medium level as analyzed data. The other level can be referring to Appendix A1 until Appendix A4. For coated graphs we can see at Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4, Figure 4.5, and Figure 4.6.

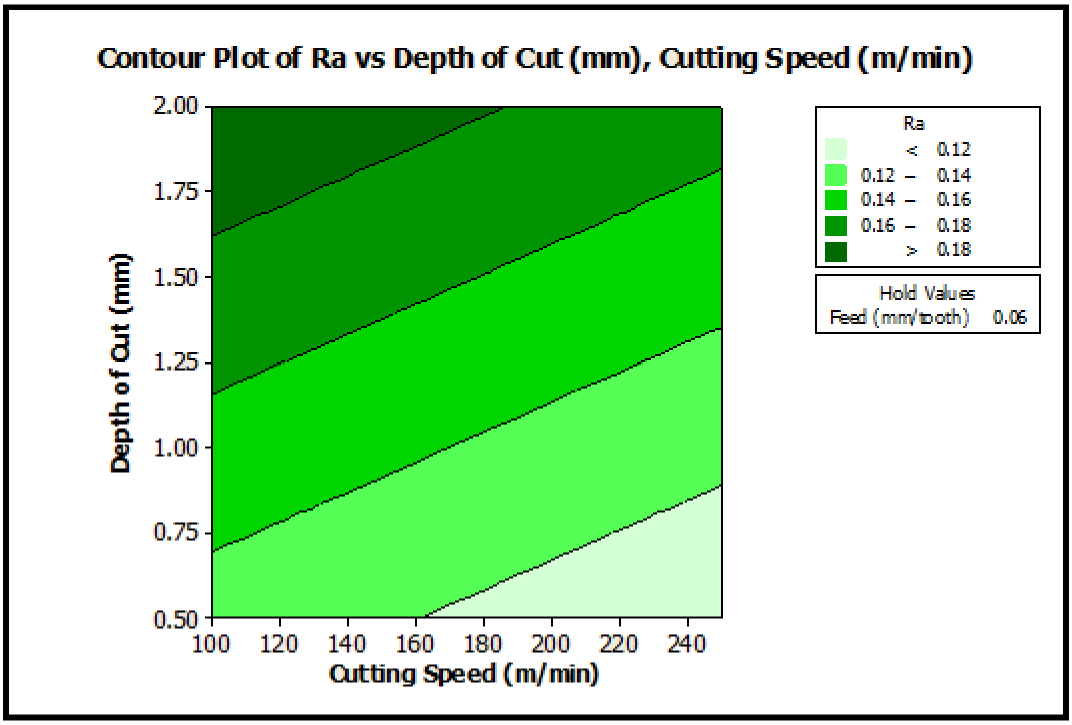

Figure 4.1 Contour plot: Depth of cut versus cutting speed. (medium level)

Based on Figure 4.1 contour plot, we can see the lowest surface roughness occur when the depth of cut is 0.5 mm and the cutting speed in range 165 m/min and above. The surface roughness increase when the depth of cut increase. In this graph the constant value is feed, 0.06 mm/tooth. The slower cutting speed the larger of surface roughness.

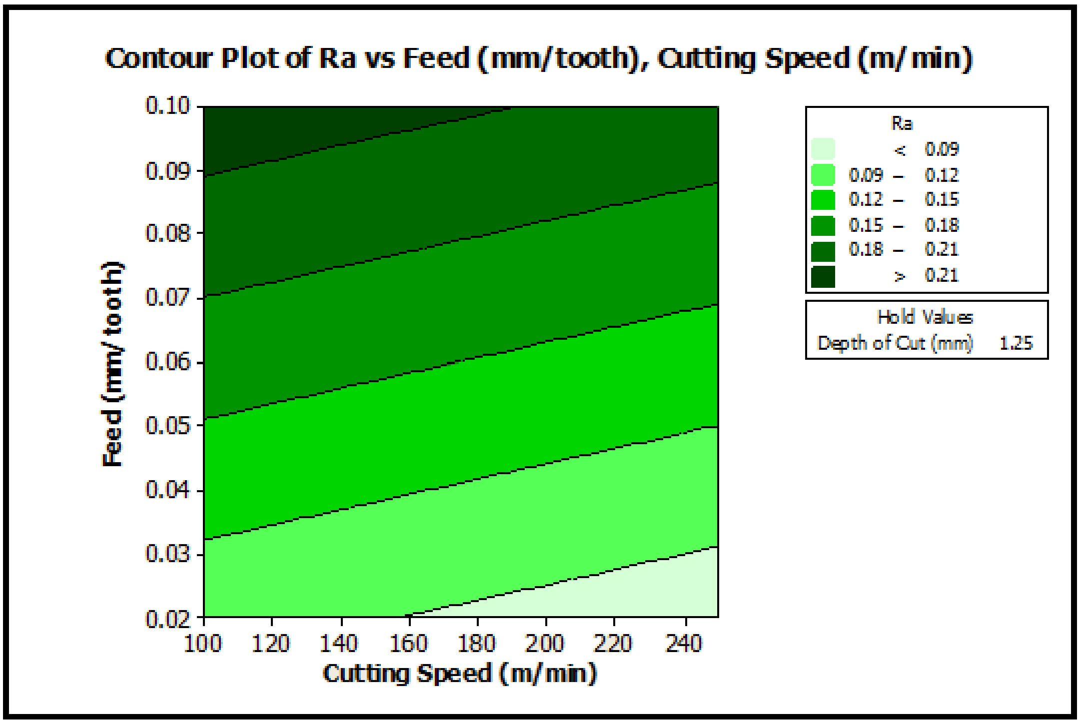

Figure 4.2 Contour plot: Feed versus cutting speed

Based on Figure 4.2, the constant of this graph is Depth of Cut with the value equal to 1.25 mm. Feed versus Cutting Speed show that both of variables fluent the surface roughness. The fine surface roughness we can get from this graph is when feed equal to 0.02 mm/tooth and the cutting speed is 160 m/min and above.

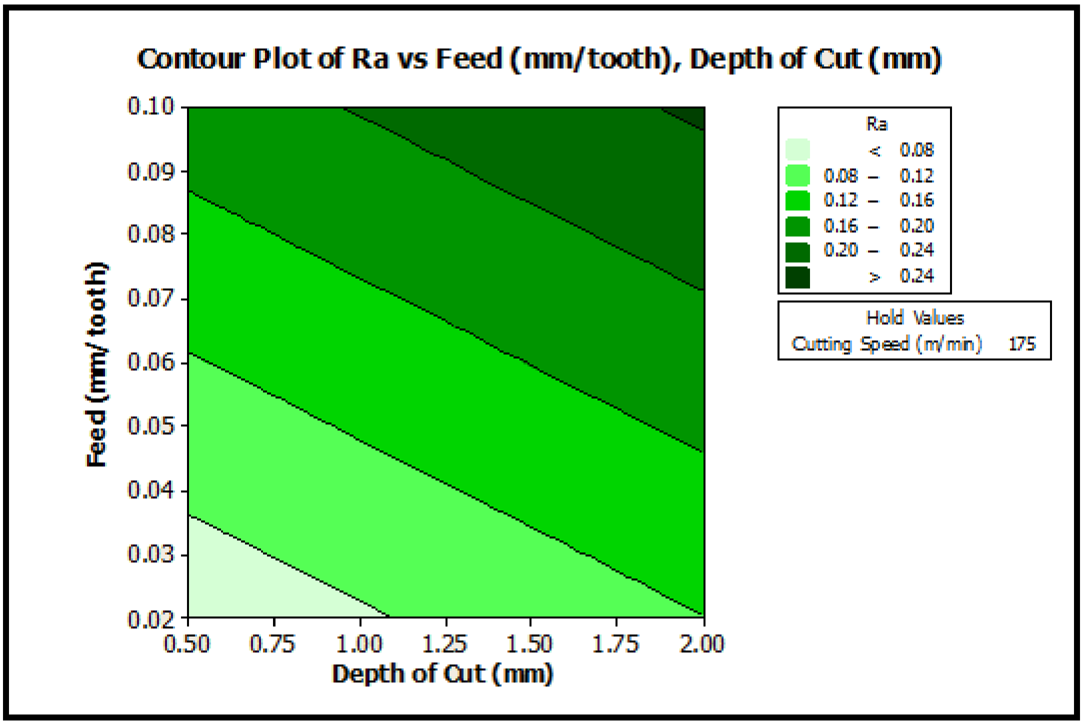

Figure 4.3 Contour plot: Feed versus depth of cut

After analyzed the Figure 4.3, the constant variable of this graph is Cutting Speed with value 175 m/mm. From this graph, we can get the good surface roughness when the feed is low and the depth of cut is low. The feed is directly proportional to the depth of cut. When depth of cut is equal to 2.00 and the feed equal to 0.10 mm/tooth the value surface of surface roughness is the highest for coated tool.

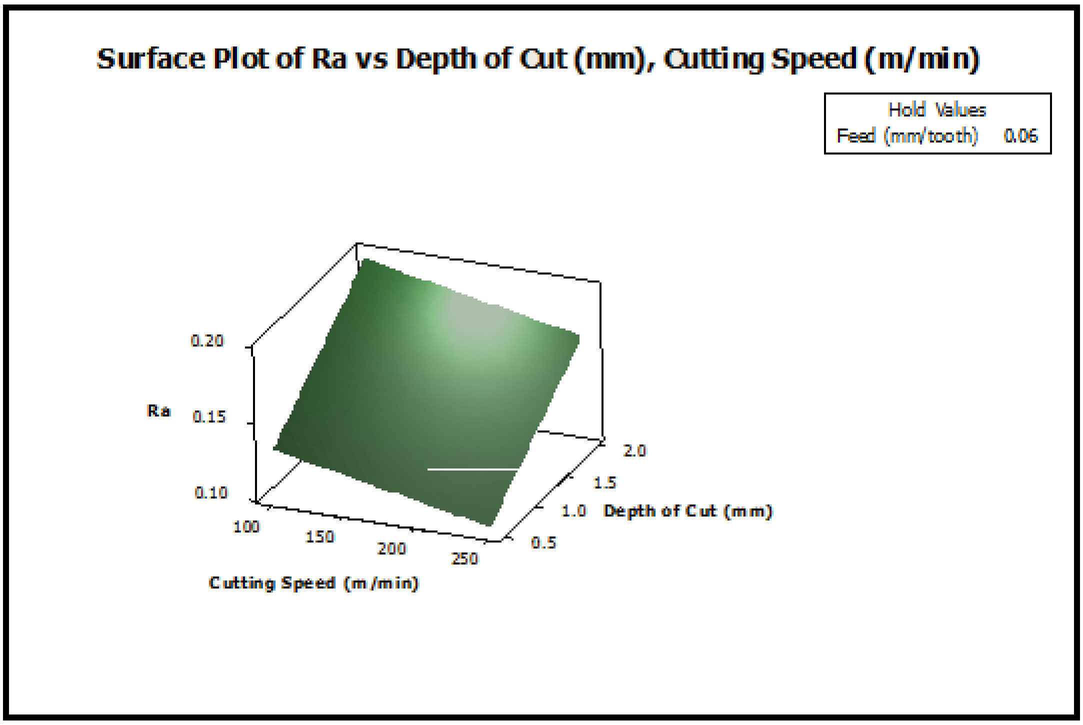

Figure 4.4 Surface plot: Ra versus depth of cut, cutting speed

From the Figure 4.4 we can see the value of Ra is lower when the cutting speed high and the depth of cut is low.for this surface plot, the constant variable is feed with value 0.06 mm/tooth.

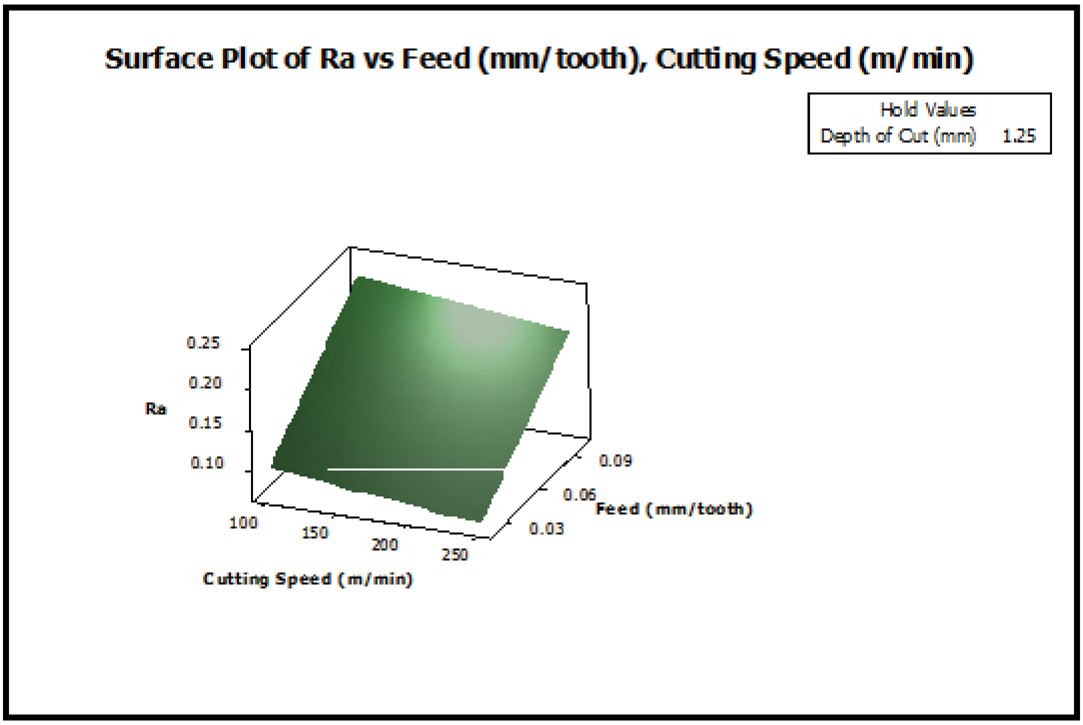

Figure 4.5 Surface plot: Ra versus cutting speed, feed

From Figure 4.5, the graph of Ra versus Cutting Speed and Feed show the finnest surface roughness is at the cutting speed equal to 250 m/min and the feed equal to 0.03 mm/tooth. The faster cutting speed the better surface roughness.

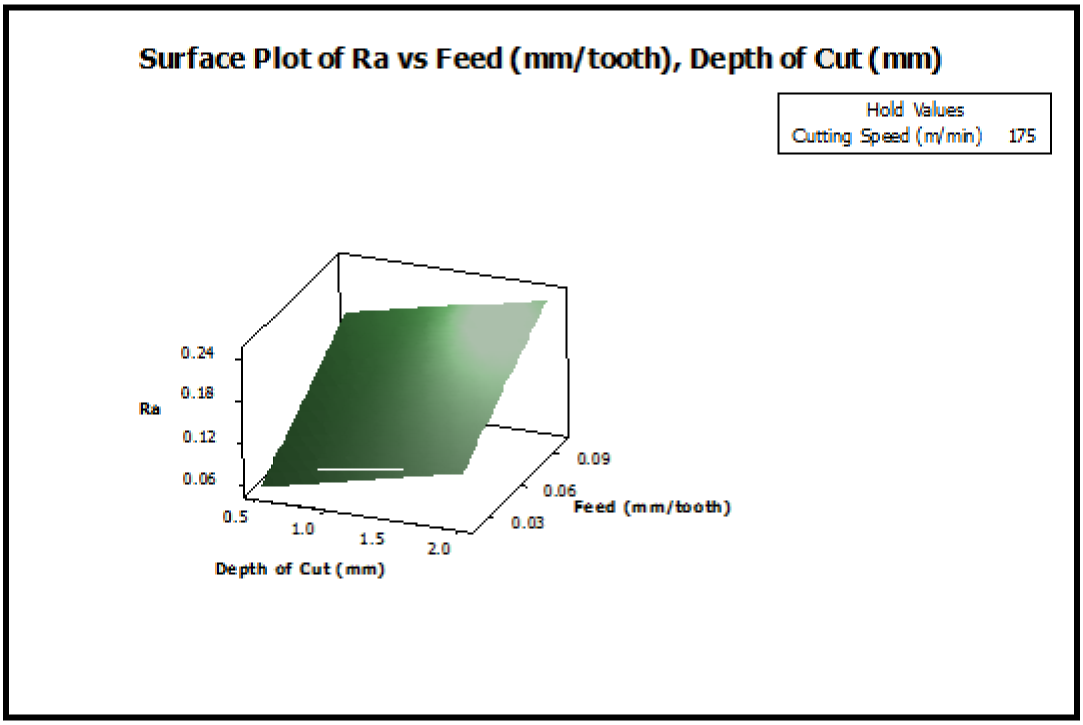

Figure 4.6 Surface plot: Ra versus feed, depth of cut

Based on Figure 4.6, the feed and the depth of cut play a role in determining good surface roughness. The greater surface roughness can be obtain when machining in low depth of cut and and feed.

For uncoated carbide tool the graphs are show as Figure 4.7, Figure 4.8, Figure 4.9, Figure 4.10, Figure 4.11, and Figure 4.12 below.

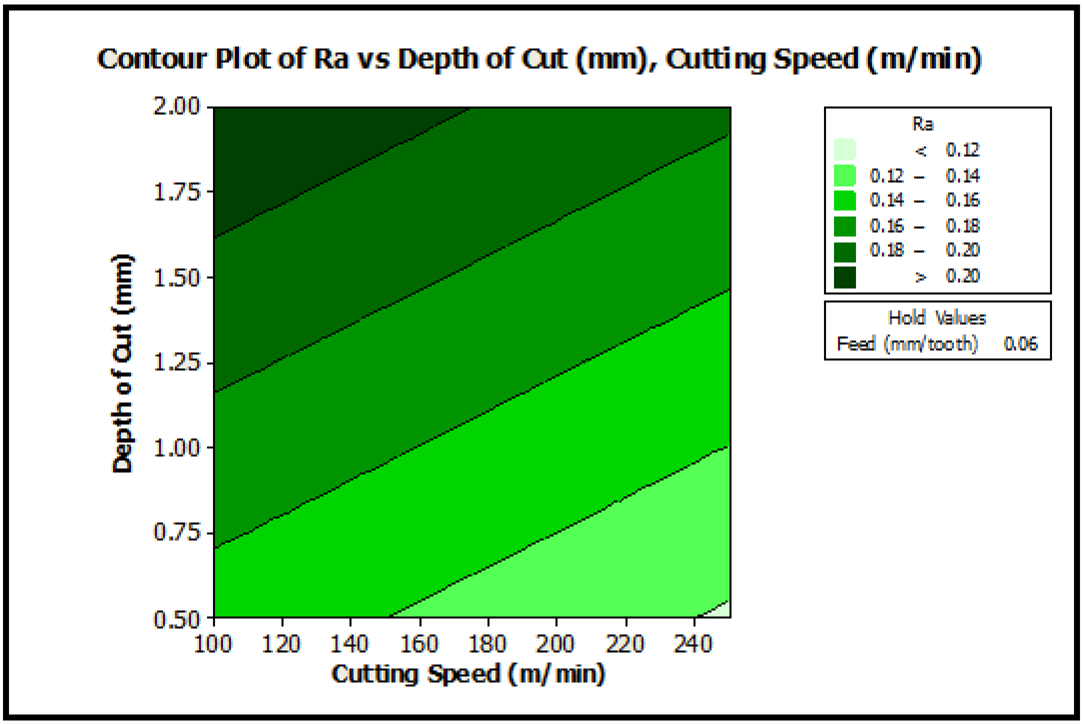

Figure 4.7 Contour plot: Depth of Cut Vs Cutting Speed. (medium level)

Based on Figure 4.7 we can see the countour plot of the depth of cut versus cutting speed. The fine surface roughness was small. The range of depth of cut is about 0.50 to 0.57 mm to get the finest surface roughness. Increasing the depth of cut show the increasing of Ra very much. Lowering the the depth of cut and increasing the cutting speed will decrease the surface roughness.

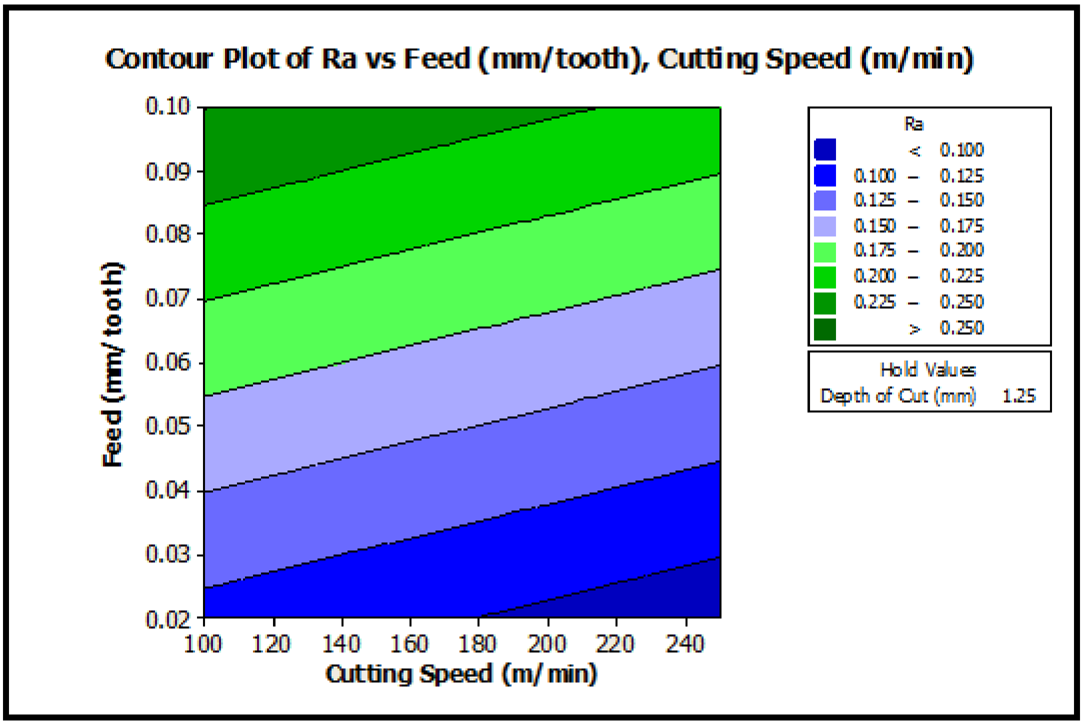

Figure 4.8 Contour plot: Feed Vs Cutting Speed.

At Figure 4.8, when the feed value equal to 0.02 mm per tooth, the relationship between high of cutting speed and lower depth of cut shown for the area of fine surface roughness value. Area of Ra is high at the value of 0.85 mm/tooth to 0.01 mm/tooth and increasing the cutting speed. These factor relationships are slowly increasing of the cutting speed to the depth of cut. Lowering the feed and increasing the cutting speed will give the fine surface roughness.

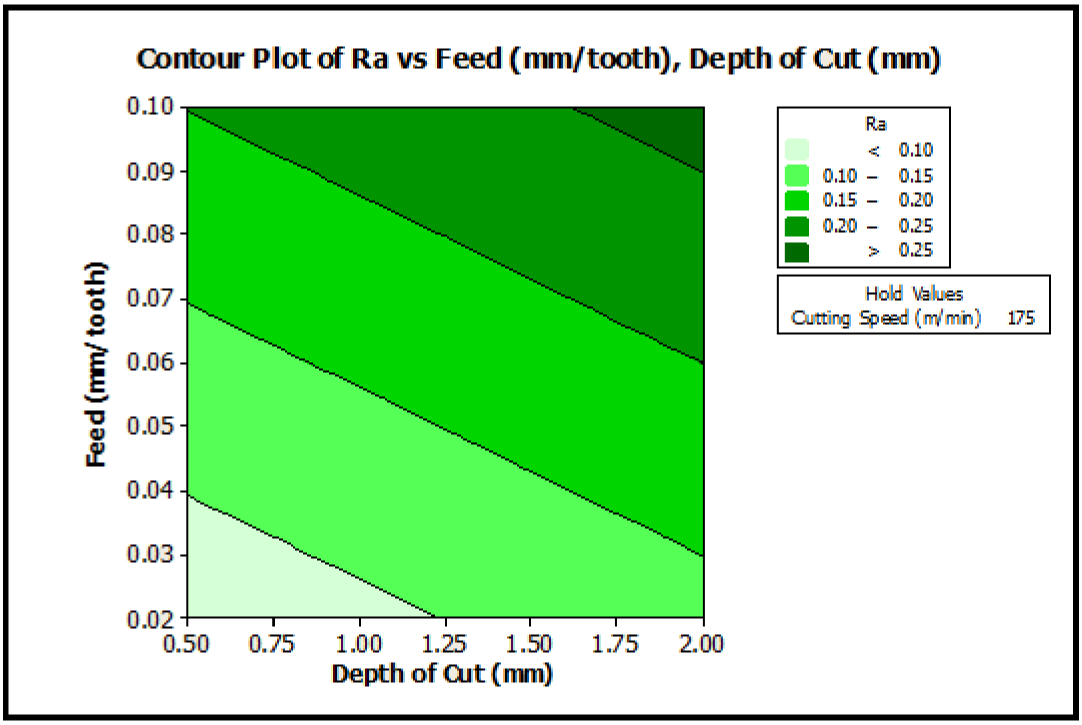

Figure 4.9 Contour plot: Feed Vs Depth of Cut

After analyzed the Figure 4.9, the constant variable of this graph is Cutting Speed with value 175 m/mm. From this graph, we can get the good surface roughness when the feed is low and the depth of cut is low. The feed is directly proportional to the depth of cut. When depth of cut is equal to 2.00 mm and the feed equal to 0.10 mm/tooth the value surface of surface roughness is very high.

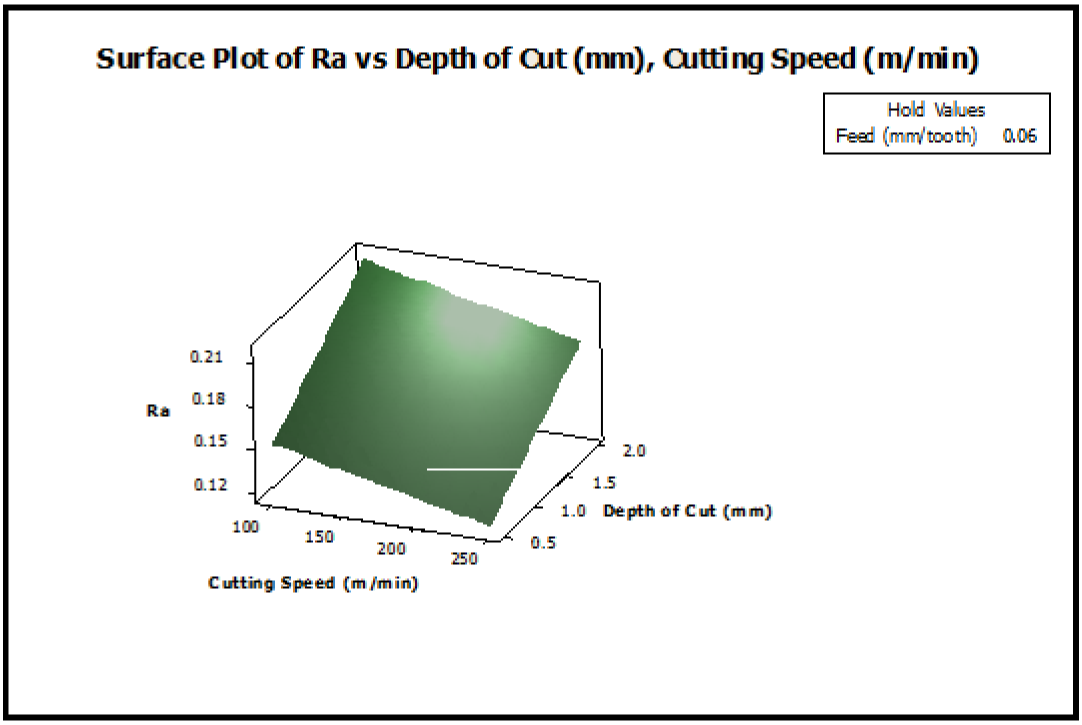

Figure 4.10 Surface plot: Ra Vs Depth of Cut, Cutting Speed.

After analyzed the Figure 4.10, we noted that uncoated tool will give good surface roughness at high cutting speed and low depth of cut. The value of Ra is 0.12 when the cutting speed is 250 m/min and 0.5 mm depth of cut. The surface roughness increase in lowering the cutting speed and increasing depth of cut.

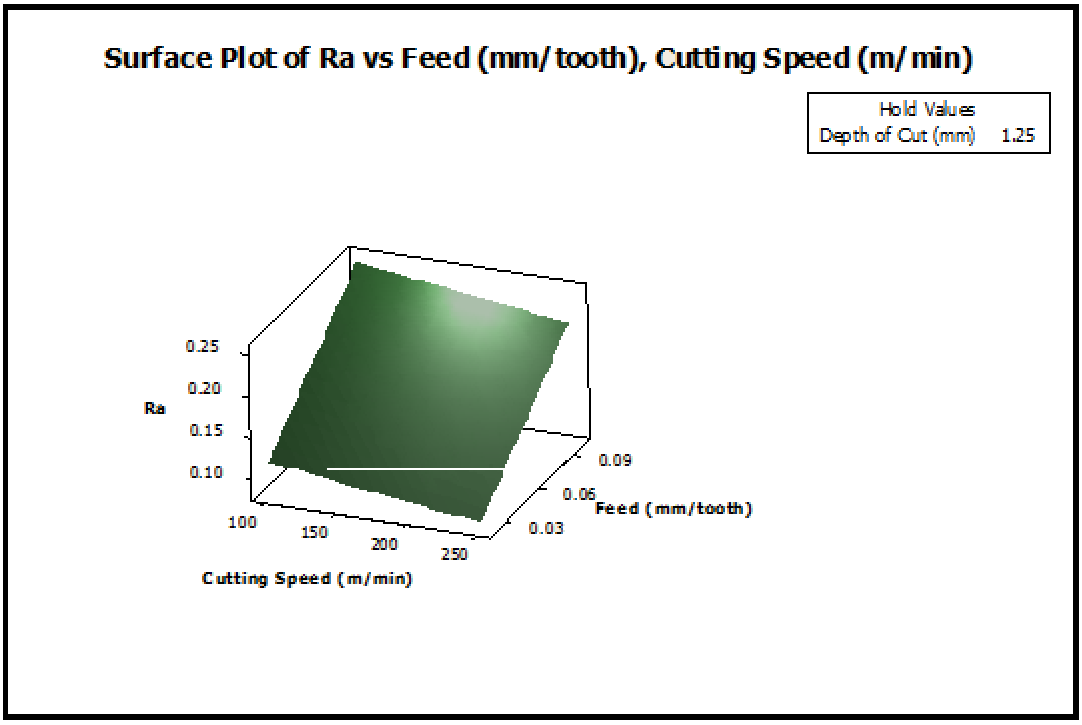

Figure 4.11 Surface plot: Ra Vs Cutting Speed, Feed

Figure 4.11; show the uncoated tool result of surface roughness of cutting speed and feed. The higher cutting speed and the lower feed will result the good surface roughness. In this graph, when the cutting speed 250 m/min and the feed is 0.02 mm/tooth, the Ra is 0.10µm

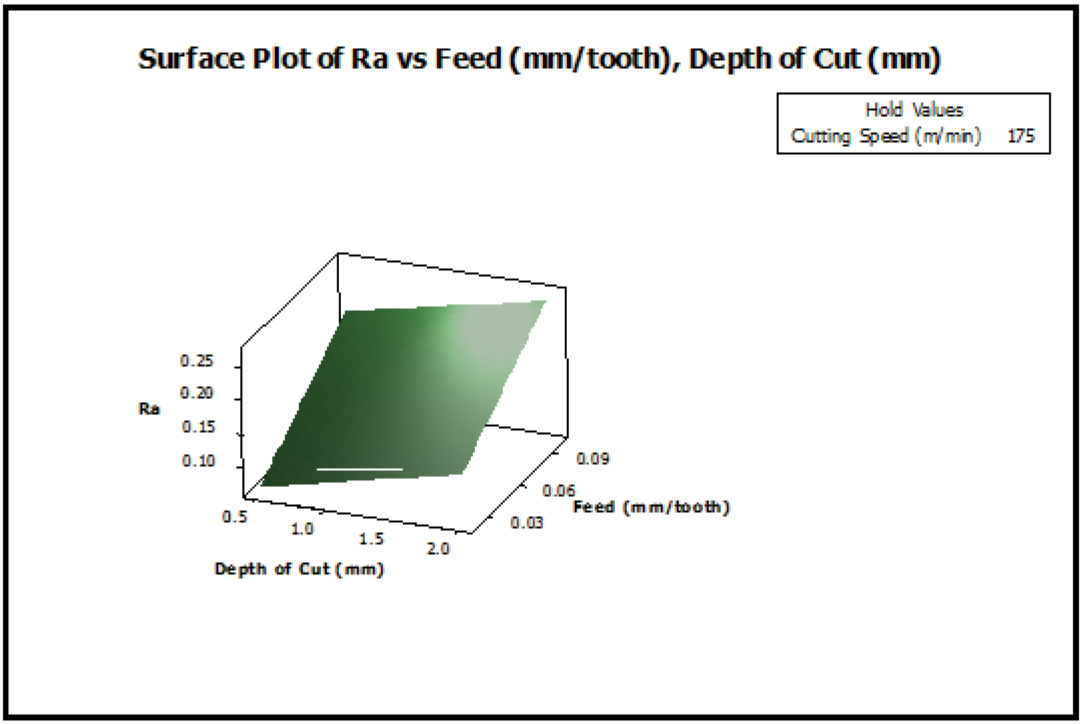

Figure 4.12 Surface plot: Ra Vs Feed, Depth of Cut

In Figure 4.12, we can see the surface plot of Ra versus feed and depth of cut. From the graph, it show the relationship between depth of cut and feed in determining Ra. We noted that lowered depth of cut and lowered feed will result the best surface roughness. When the depth of cut is 0.5 mm and the feed is 0.05 mm/tooth the Ra is 0.1.

4.4 Comparison of the coated and uncoated carbide tools in surface roughness

After all the data had been analyzed, we can make a comparison of the performance of coated and uncoated carbide tools in term of surface roughness. From Figure 4.1 to Figure 4.12, we can observe that coated carbide tools give better surface roughness which means lower Ra in machining aluminium alloy.

The value of Ra obtained for coated carbide tool lied between 0.52µm to 0.306µm from table 4.1 while the value of Ra obtained for uncoated carbide tool lied between 0.092µm to 0.326µm from table 4.2. The wear pattern of the coated-tool may have an influence on the surface roughness since the damage on the cutting edge was less when compared to uncoated-tools.

After comparison between Figure 4.1 and Figure 4.5, it shows the region of finest surface roughness of coated carbide tool are wider than uncoated carbide tool. The region was taken when the depth of cut is equal to 0.05 mm, it show the cutting speed region of coated carbide tool lied on 165 m/min and above. Meanwhile for the uncoated carbide tool, the cutting speed region lied on 240 m/min and above. So that, it show the coated carbide tool need lower cutting speed in order to get the good surface roughness.

In order to get the finest surface roughness of aluminum alloy, the depth of cut must be suitable. For coated carbide tool, the best range of depth of cut is between 0.5mm to 1.75mm for 0.02 mm/tooth as it feed (Figure 4.3). For uncoated carbide tool, the best range of depth of cut lied on 0.5mm to 1.24mm for 0.02 mm/tooth as it feed (Figure 4.9). With this two data we can see that the coated carbide tools have wider range in depth of cut. Coating material shows the improvement of cutting depth in order to get the good surface roughness.

As the surface coating material has high hardness and wear resistance, and high temperature. Therefore, with the uncoated tool than coated tools allows high cutting speed, thus improving cutting efficiency or in the same cutting speeds, improve tool life. As the coating material and the material being processed between the friction coefficient smaller, so coated tool of the cutting force smaller than the uncoated tool with the coated tool processing, and parts machined surface quality is better. As the coated tool of the overall performance well and coated carbide inserts have better general, a coated carbide tool has a wide scope of use.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter will conclude the research and briefly discussed about the recommendation that can be applied for the future work. The conclusion were done according to the result obtain from chapter 4 which is to study the performance of coated and uncoated carbide tool in machining aluminum alloy.

5.2 CONCLUSION

Several conclusions that can be drawn from the study are:

i. The coated carbide tool is very suitable in machining aluminum alloy compare to uncoated carbide tool. The value of Ra obtained for coated carbide tool lied between 0.52µm to 0.306µm
ii. The surface roughness of coated tool carbide tool can be fine when the cutting speed is 160 m/min, depth of cut is 0.5mm and feed is 0.02 mm/tooth.
iii. The surface roughness of uncoated tool carbide can be fine when the cutting speed is 240 m/min, depth of cut is 0.5mm and feed is 0.06 mm/tooth.

5.2 Recommendation

There are few improvements need to do for the future research. This is to improve the accuracy of performance of coated and uncoated carbide tool while dry machining aluminum alloy. Some of the recommendations are:

i. The value of Ra is taking in several of time.
ii. Determining the tool life both, coated and uncoated carbide tools.
iii. Make a count on wear occur because it may fluent the surface roughness of the aluminum alloy.

REFERENCES

Che Haron, C.H., Ginting, A. and Goh, J.H. 2001.Wear of Coated and Uncoated Carbide tool in turning tool steel. *Journal of Materials Processing Technology* **116**:49-54

Horsfall, R. and Fontana, R. 1993. TiAlN coatings beat the heat, Cutting Tool Eng. February 37±42.

Jayaram, G, Marks, L.D. and Hilton, M.R. 1995. Surf. Coat. Technol. 76/77 393±399.

Kalpakjian, S. and Schmid, S. Manufacturing Engineering and Technology, Tool life: wear and failure, 5th edition in SI unit

Kurimoto, T. and Barrow, G. 1982. The influence of aqueous Fluids on the wear characteristics and life of carbide cutting tools,Ann. CIRP 31 (1)

Narutaki, N., Yamane, Y., Tashima, S. and Kuroki, H. 1997. A new advanced ceramic for dry machining, Ann. CIRP 46 (1)

Santhanakrishnan, G. 1994. Tribological aspects in composite machining, Ph.D. Dissertation, Indian Institute of Technology, Madras, India.

Sharif, S. and Rahim, E.A. 2007. Performance of coated- and uncoated-carbide tools when drilling titanium alloy—Ti–6Al4V. *Journal of Materials Processing Technology* 185: 72–76

Sreejith*, P.S. and Ngoi, B.K.A. 1999. Dry machining, School of Mechanical and Production Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, Singapore.

Sreejith, P.P.S. and Sreejith, S. 2007. Machining of 6061 aluminium alloy with MQL,dry and flooded lubricant conditions, Department of Mechanical Engineering, Cochin University of Science and Technology, Kochi — 682 022, Kerala, India.

APPENDIX A1

Graph for low level. (Coated carbide tool)

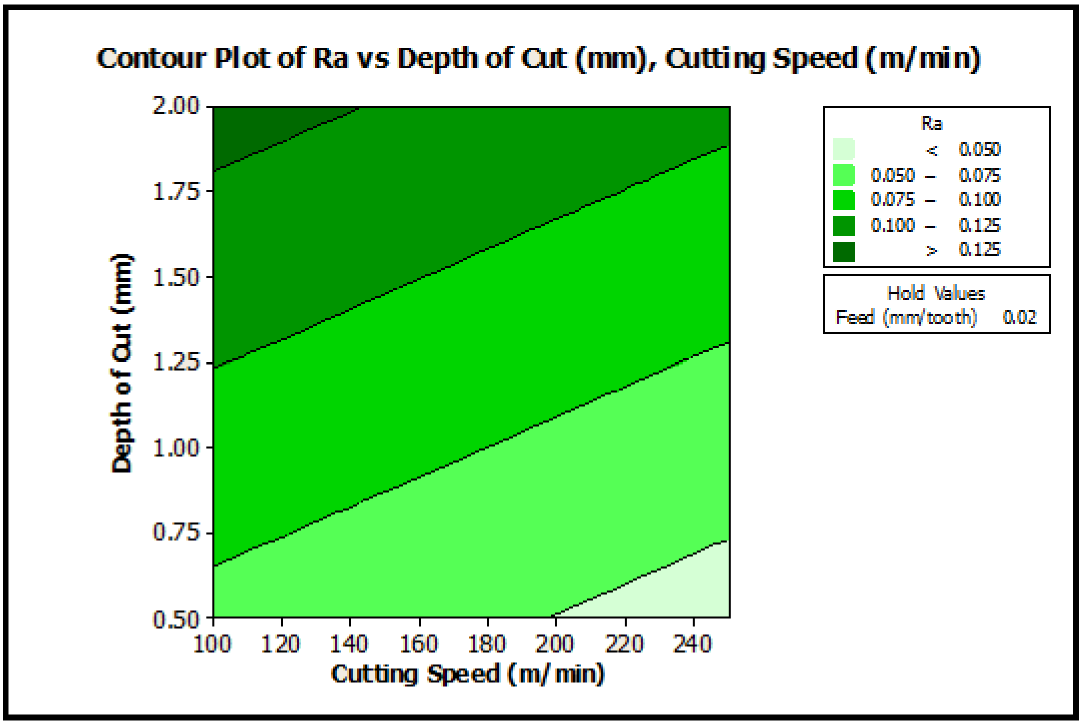

Figure 6.1 Contour plot: Depth of cut vs cutting speed

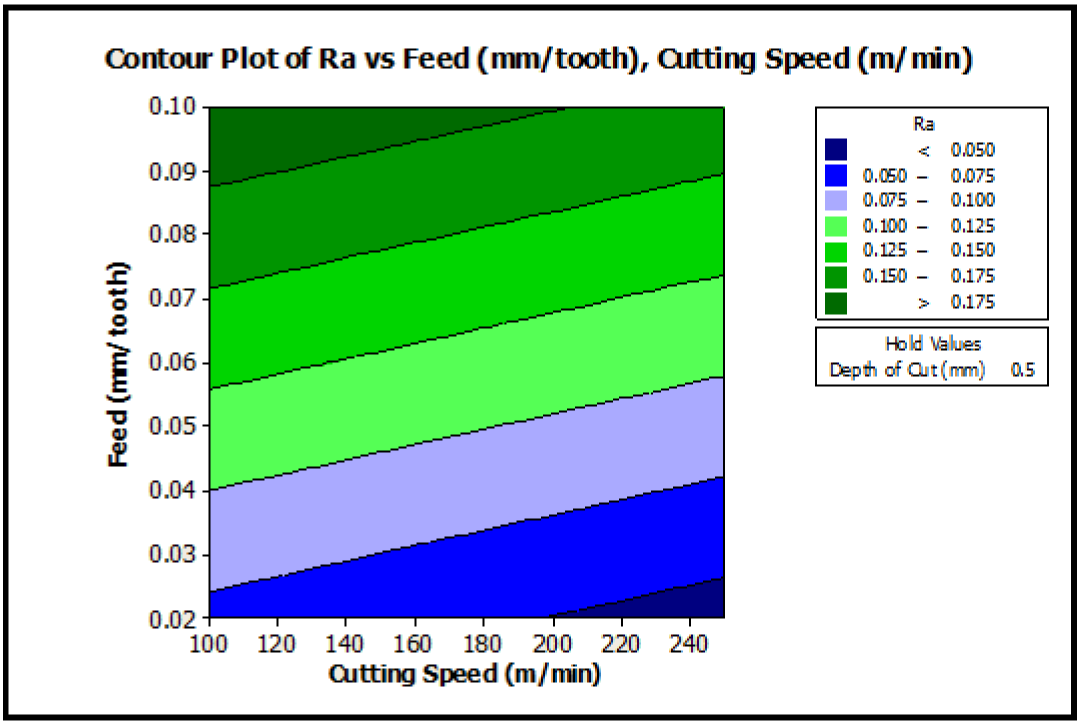

Figure 6.2 Contour plot: Feed vs. cutting speed

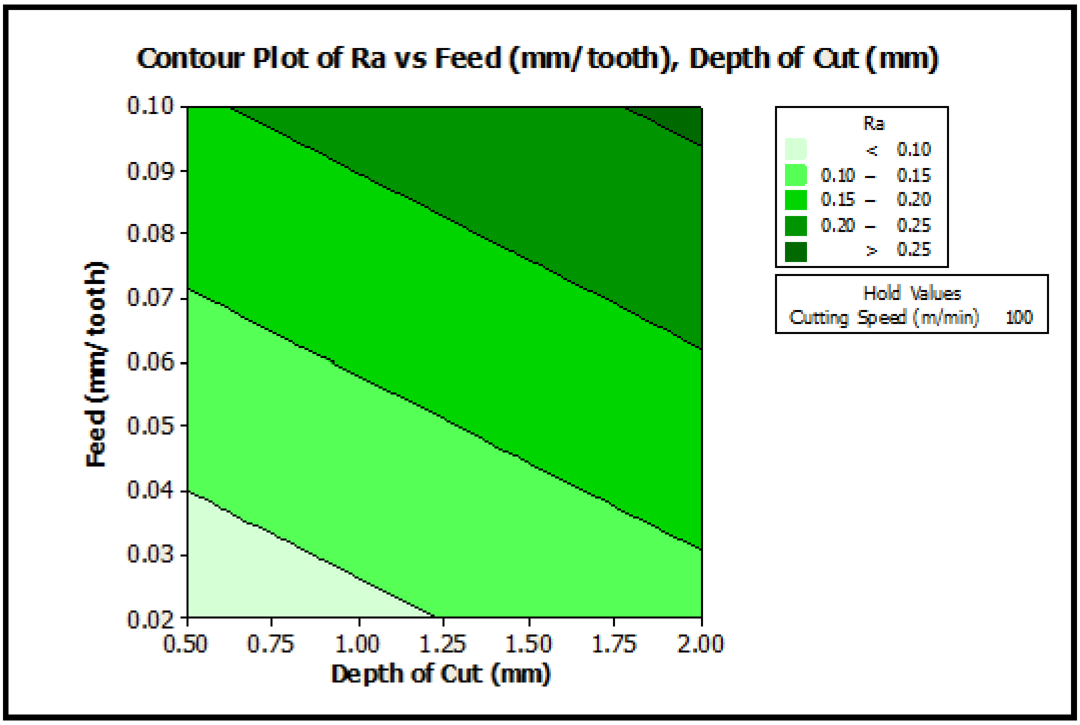

Figure 6.3 Contour plot: Feed vs. depth of cut

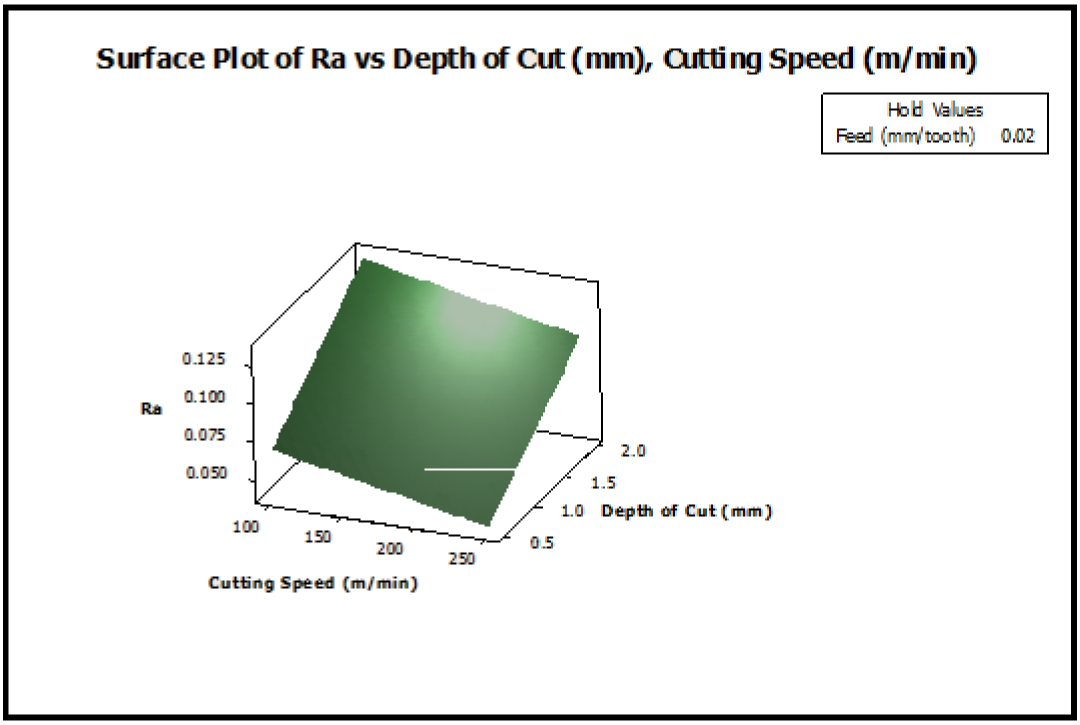

Figure 6.4 Surface plot: Ra vs. cutting speed, depth of cut

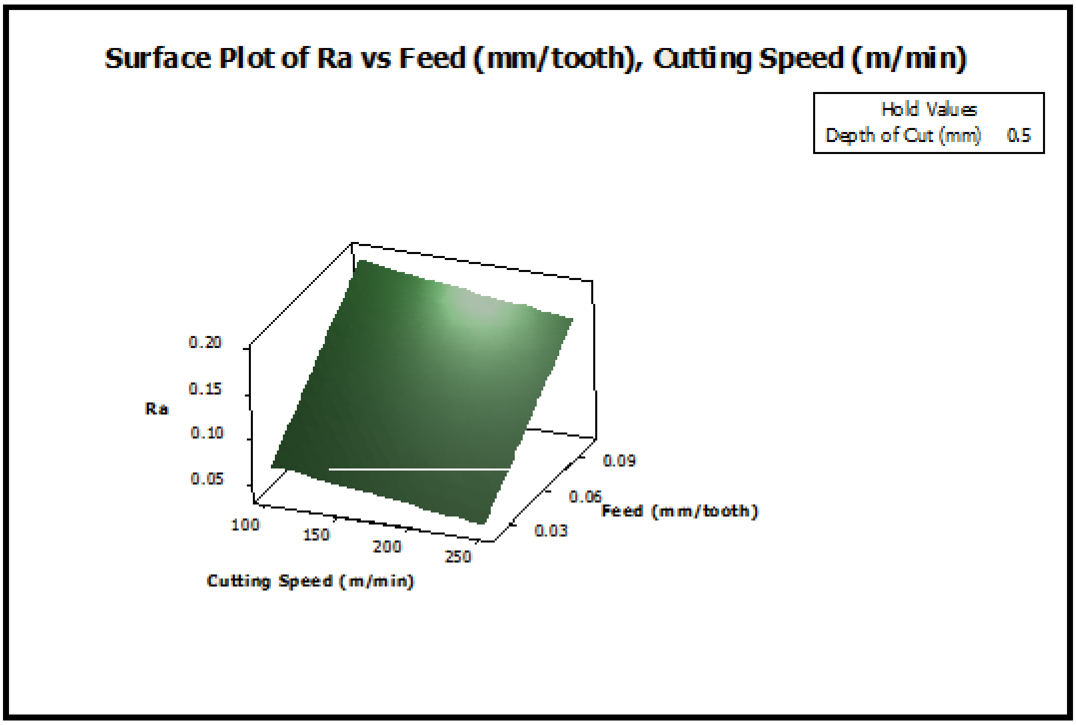

Figure 6.5 Surface plot: Ra vs. cutting speed vs feed

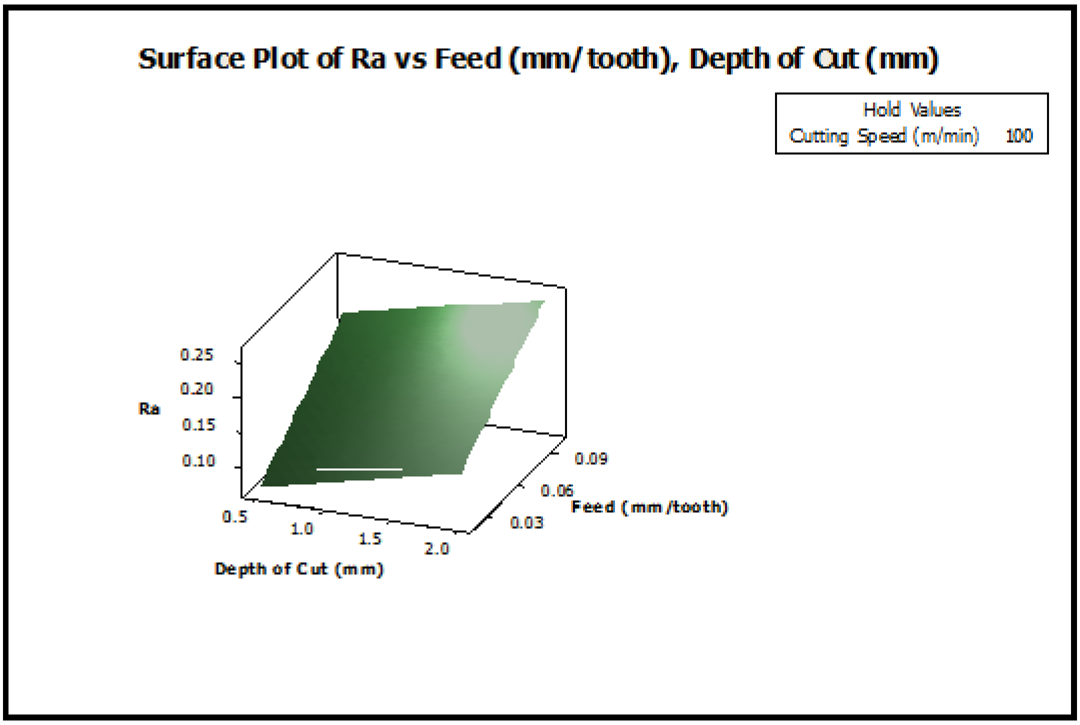

Figure 6.6 Surface plot: Ra vs. depth of cut, feed

APPENDIX A2

Graph of high level (coated carbide tool)

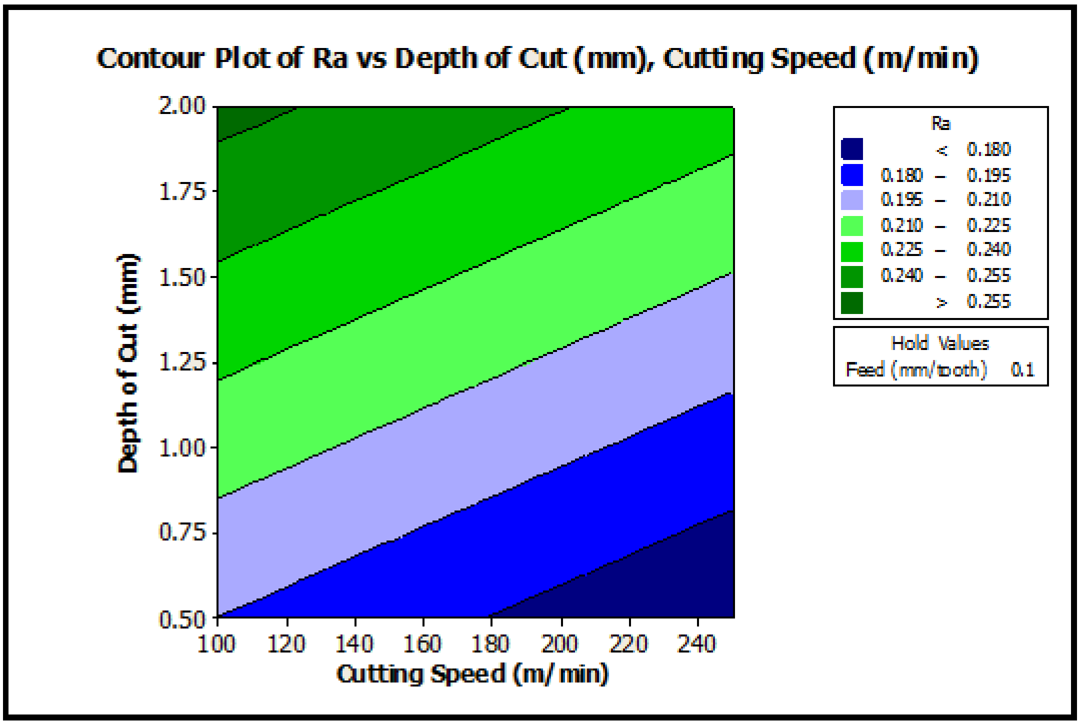

Figure 6.7 Contour plot: Depth of cut vs. cutting speed

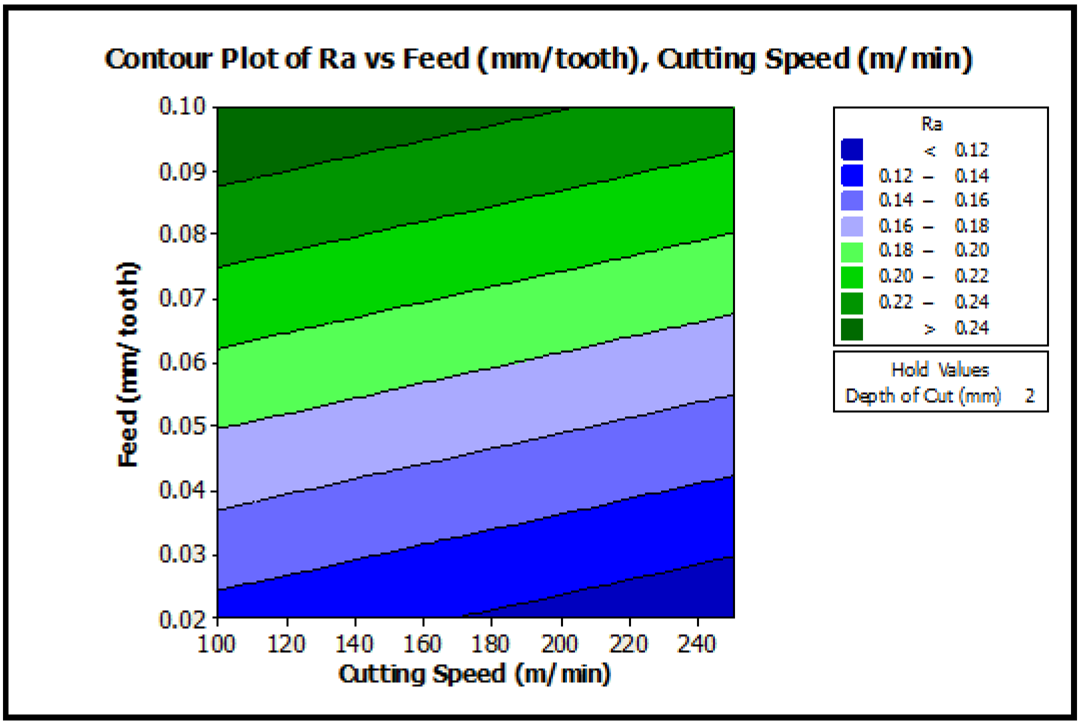

Figure 6.8 Contour plot: Feed vs. Cutting Speed

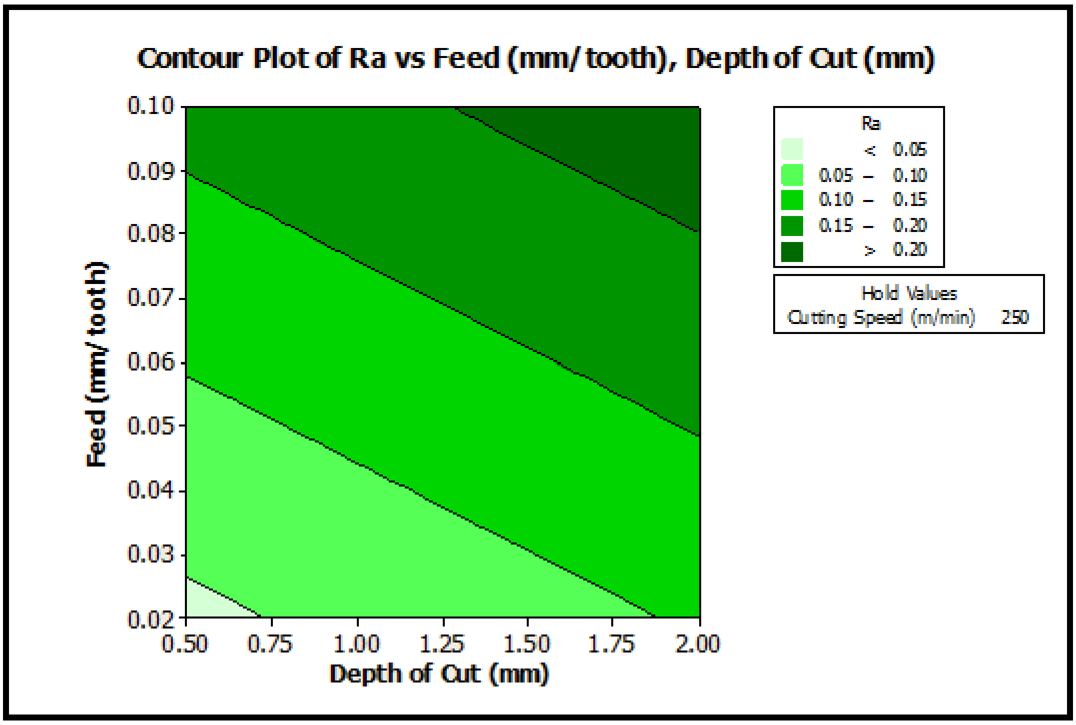

Figure 6.9 Contour plot: Feed vs. depth of cut

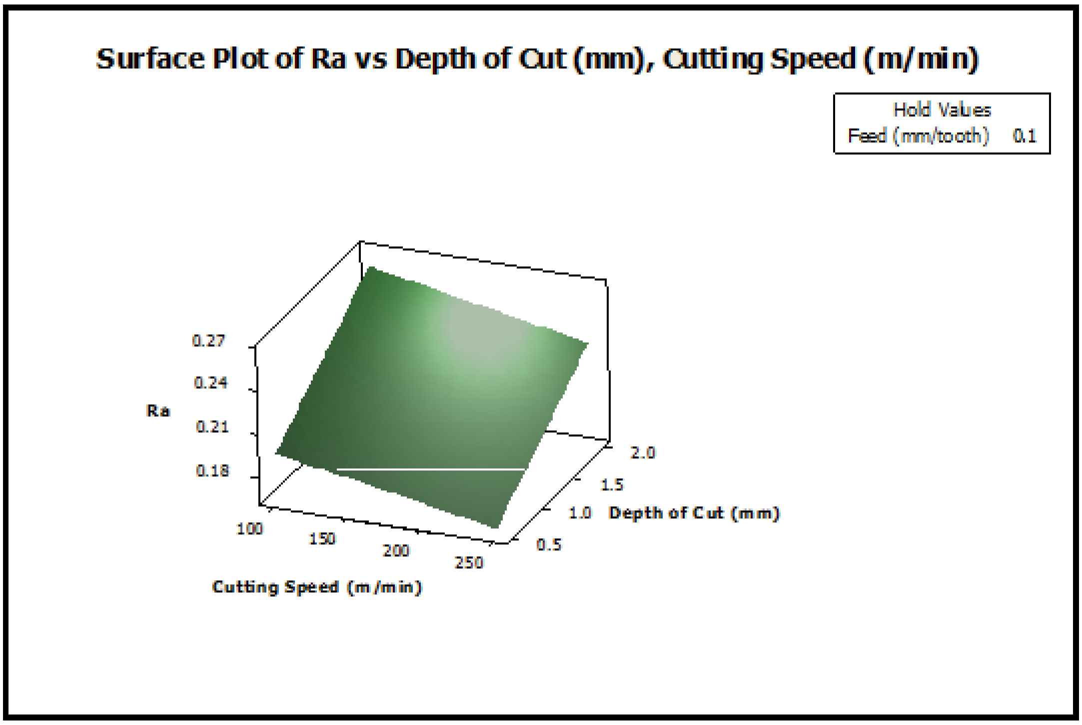

Figure 6.10 Surface plot: Ra vs. cutting speed, depth of cut

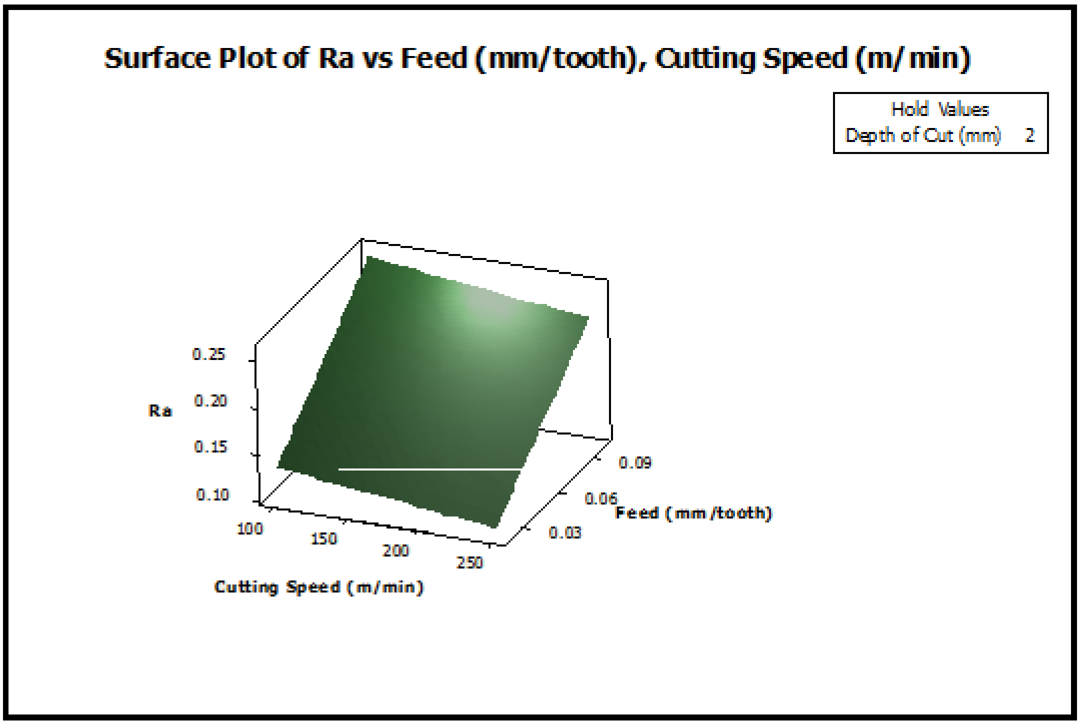

Figure 6.11 Surface plot: Ra vs. cutting speed vs feed

APPENDIX A3

Graph of low level (uncoated carbide tool)

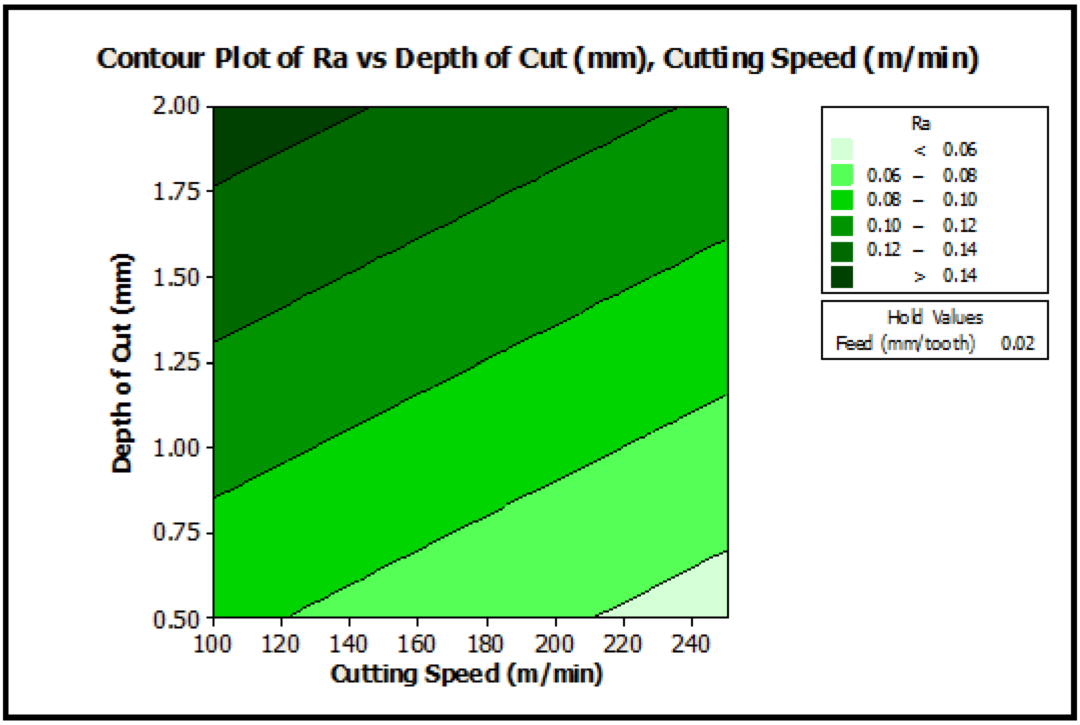

Figure 6.12 Contour plot: Depth of cut vs. cutting speed

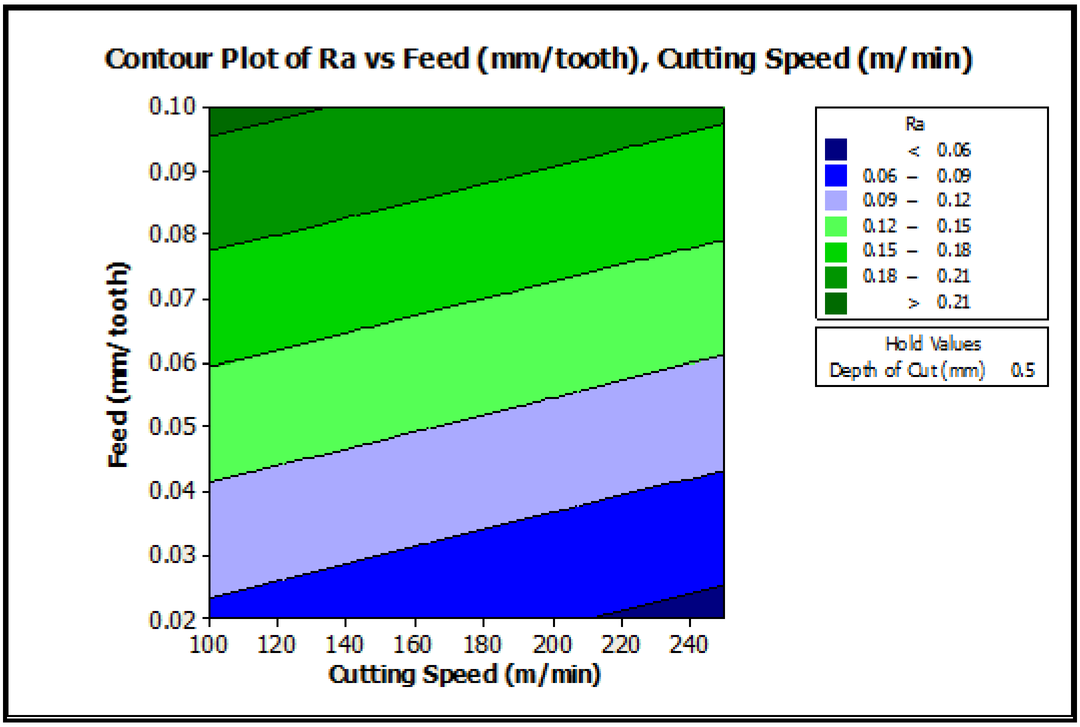

Figure 6.13 Contour plot: Feed vs. cutting speed

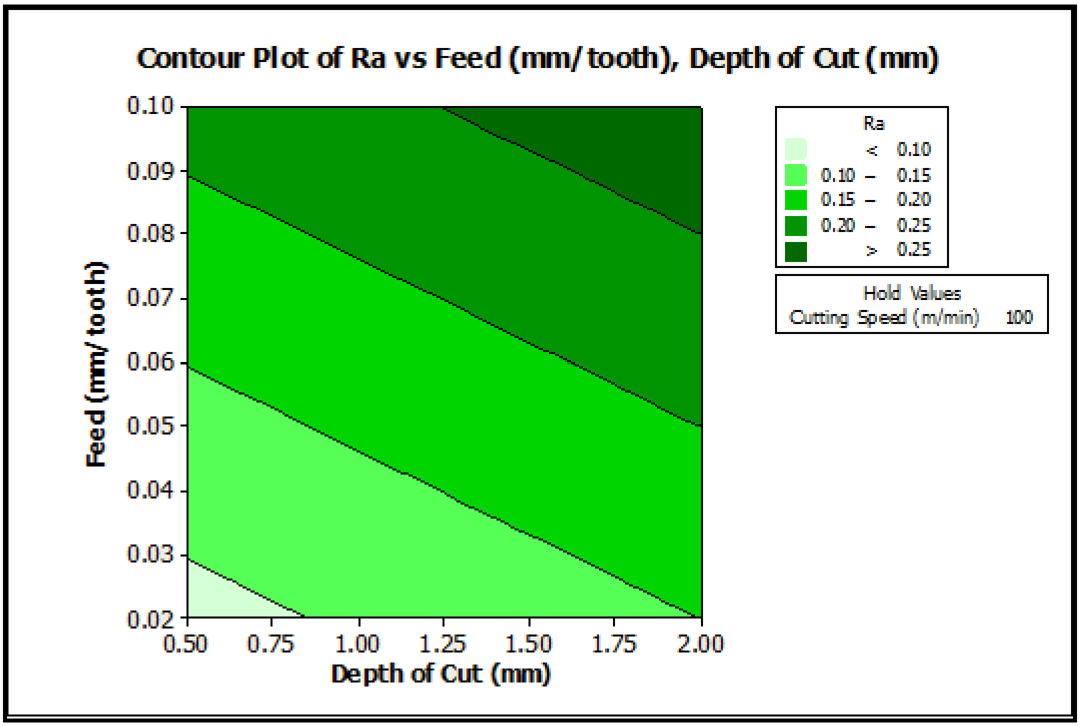

Figure 6.14 Contour plot: Feed vs. depth of cut

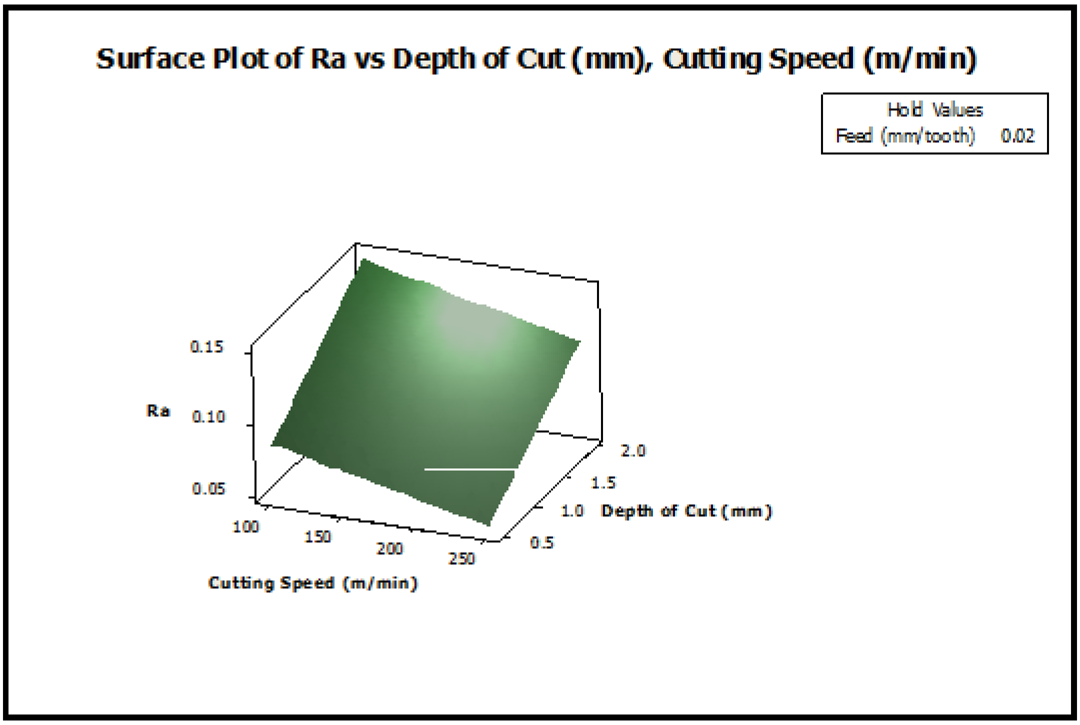

Figure 6.15 Surface plot: Ra vs. cutting speed, depth of cut

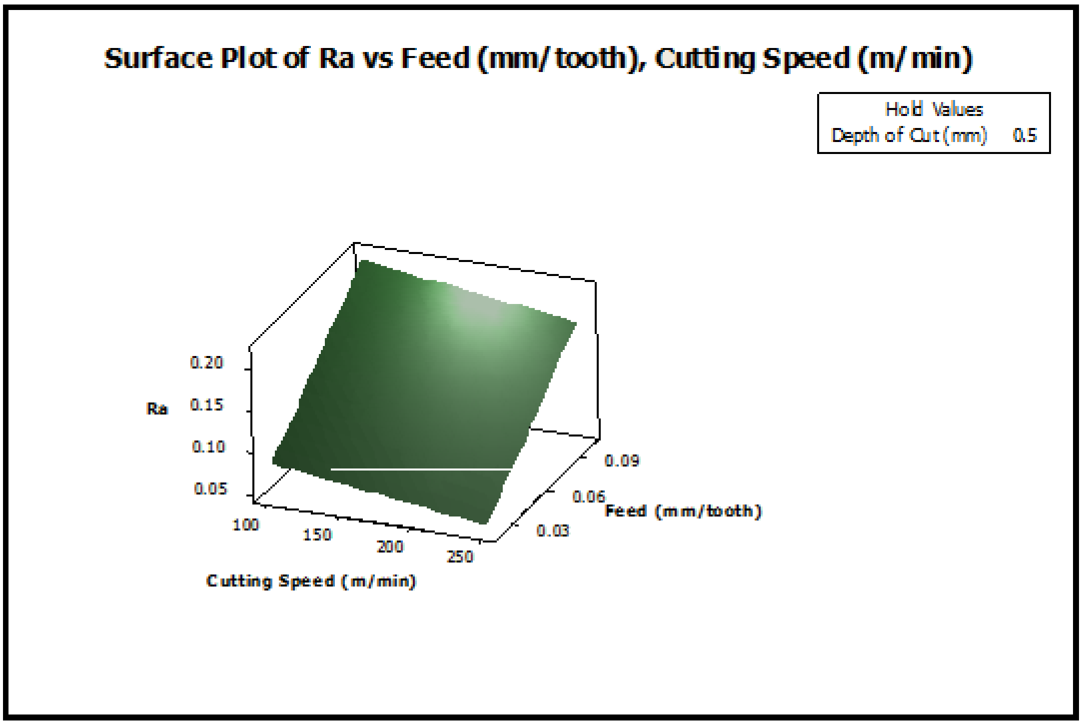

Figure 6.16 Surface plot: Ra vs. depth of cut, feed

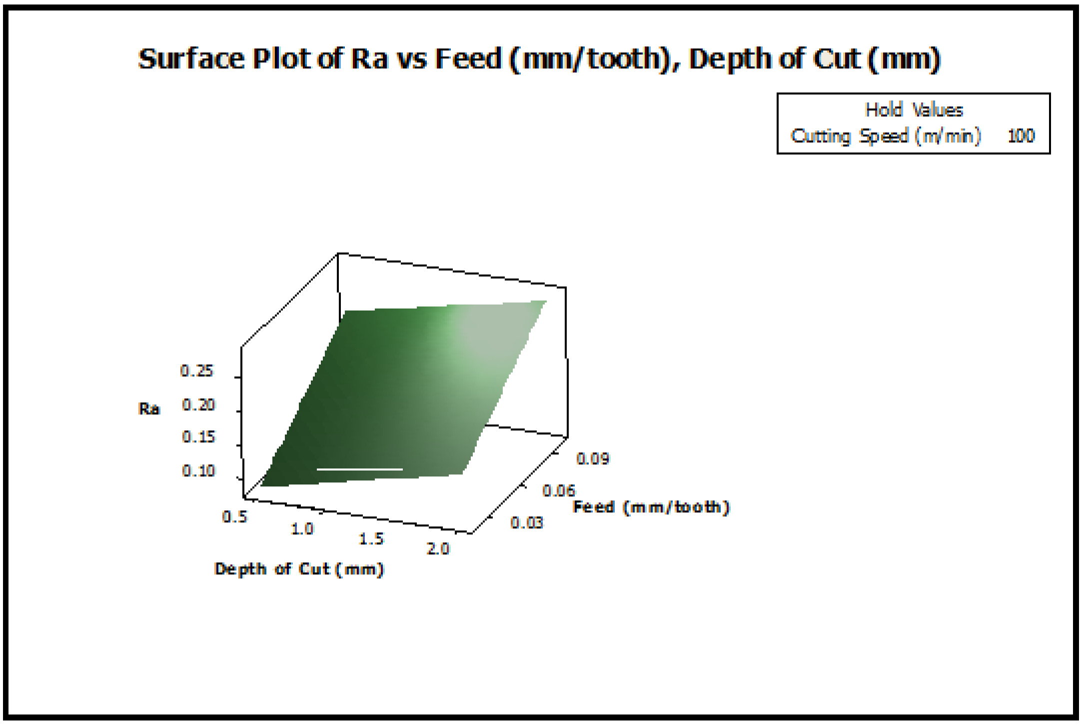

Figure 6.17 Surface plot: Ra vs. cutting speed, feed

APPENDIX A4

Graph of high level. (Uncoated carbide tool)

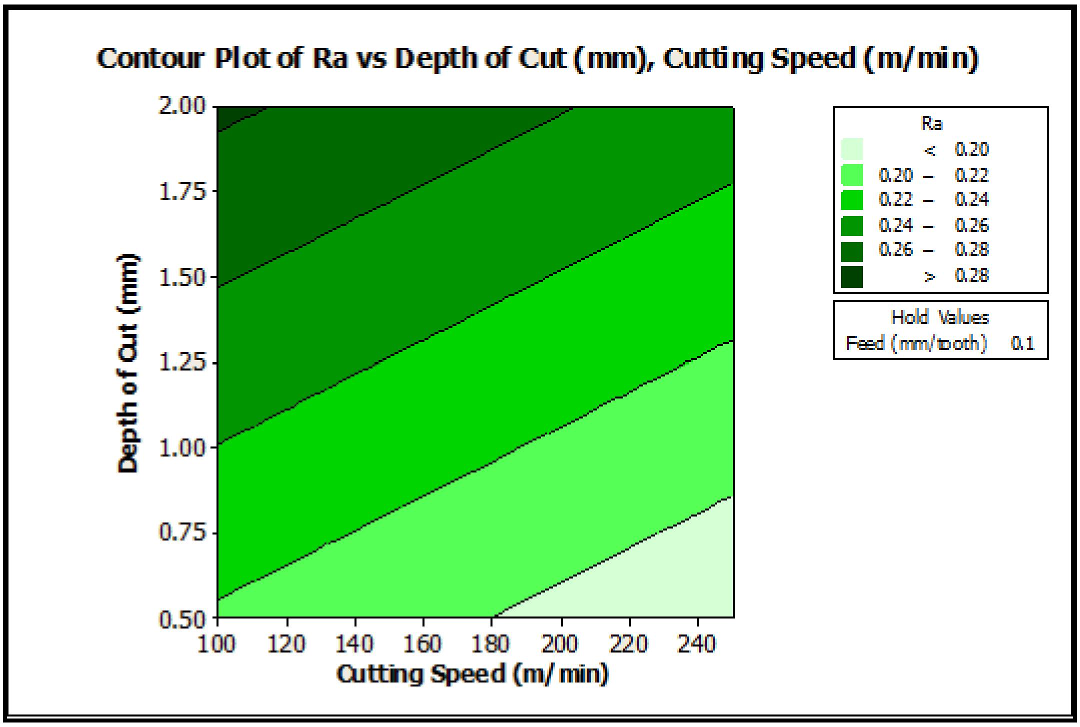

Figure 6.18 Contour plot: depth of cut vs. cutting speed

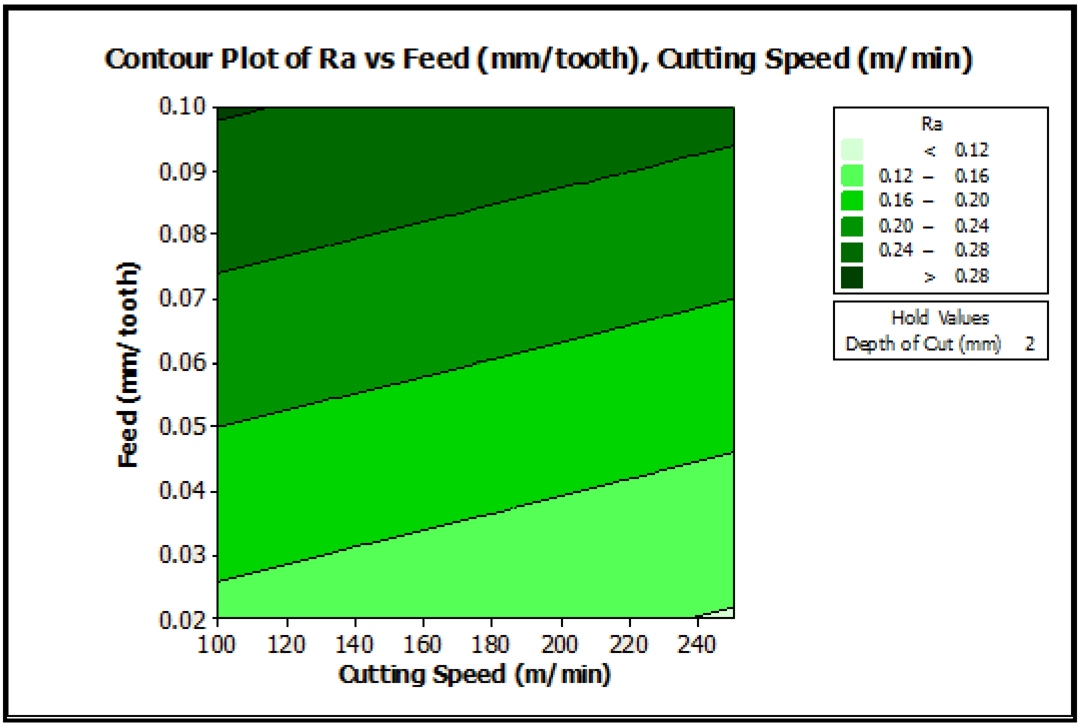

Figure 6.19 Contour plot: Feed vs. cutting speed

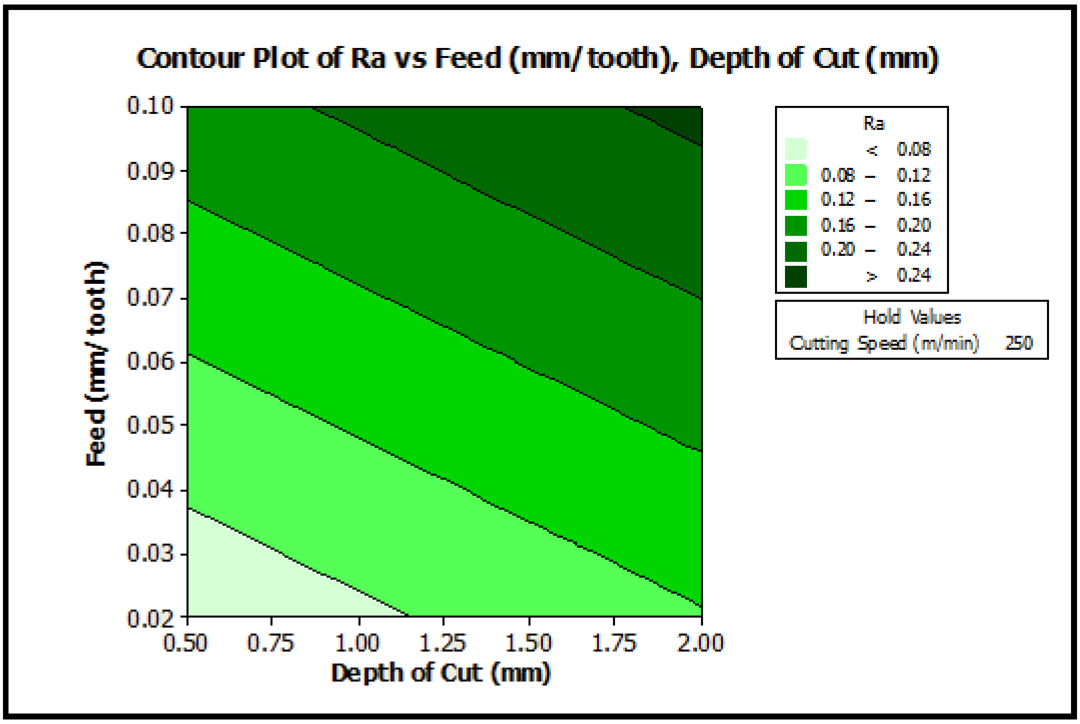

Figure 6.20 Contour plot: Feed vs. depth of cut

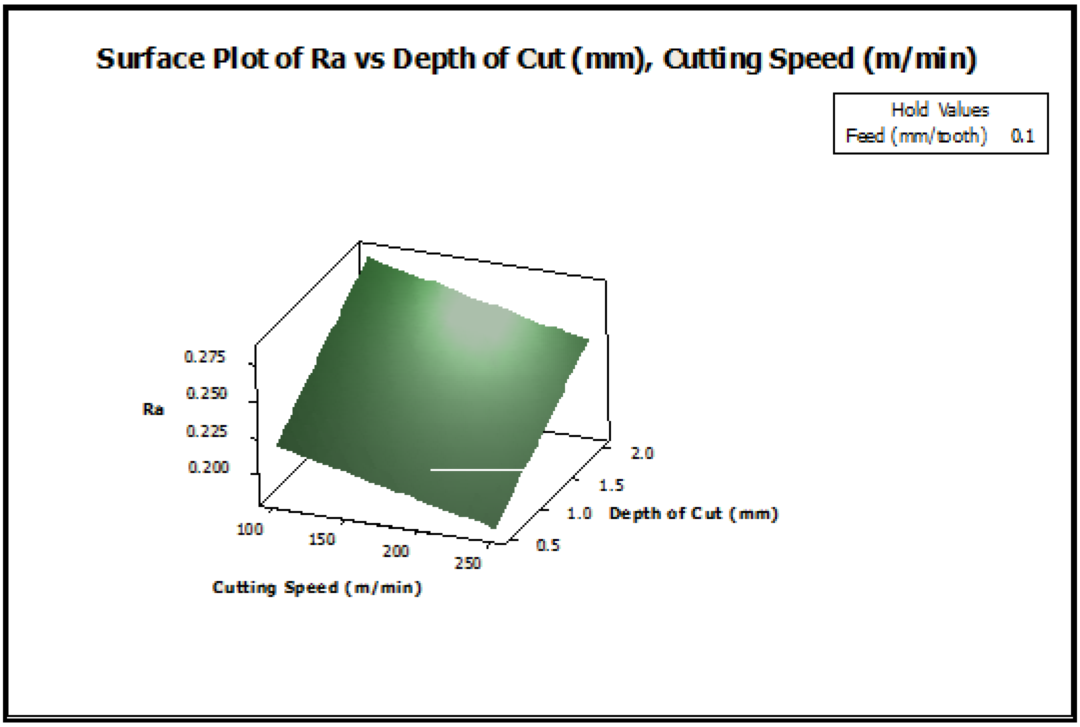

Figure 6.21 Surface plot: Ra vs. cutting speed, depth of cut

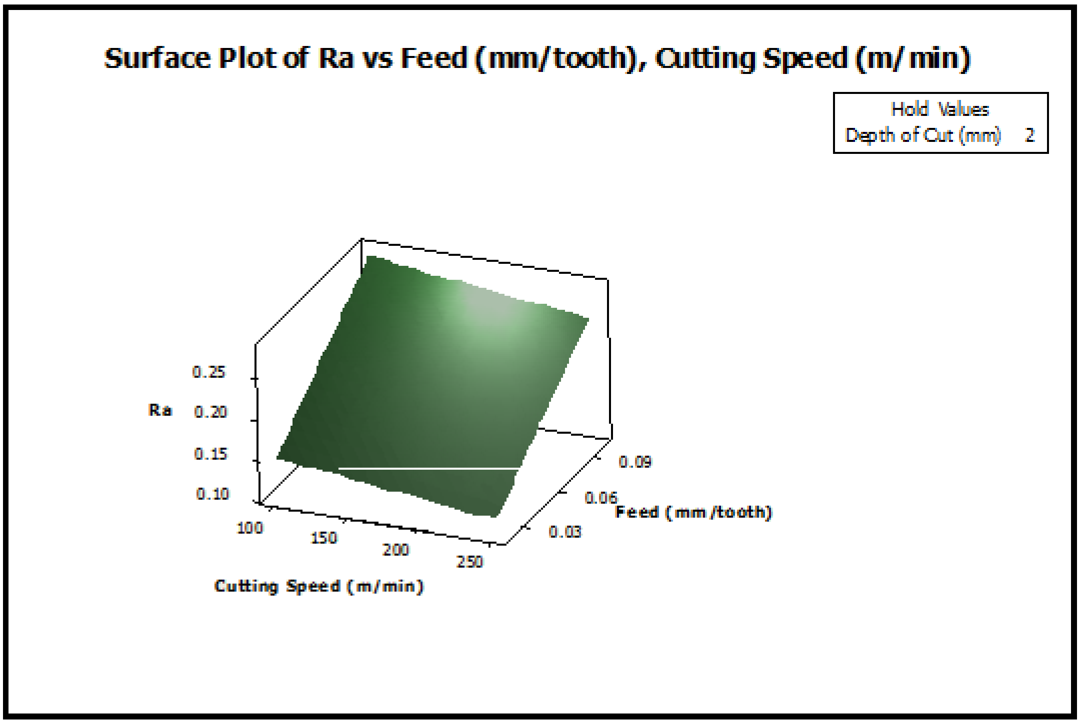

Figure 6.22 Surface plot: Ra vs. depth of cut, feed

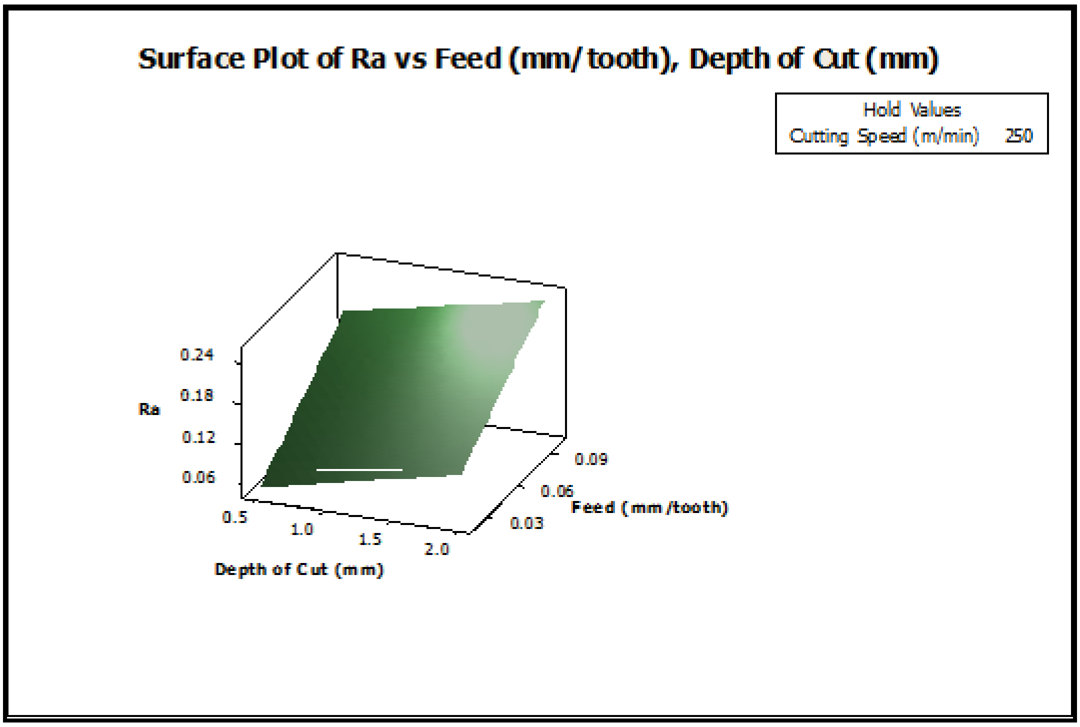

Figure 6.23 Surface plot: Ra vs. cutting speed, feed

APPENDIX B1

GANTT CHART / PROJECT SCHEDULE FOR FYP 1

ACTIVITY/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Receive title from faculty and arrange discussion time with supervisor															
Meeting with supervisor															
The rough idea about the project															
Learning the theory															
Do research and collect the information															
Prepare for chapter 1															
Prepare for chapter 2															
Prepare for chapter 3															
Prepare for presentation															
Project presentation															

APPENDIX B2

GANTT CHART / PROJECT SCHEDULE FOR FYP 2

ACTIVITY/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15-18	19	20
Experiment Set-up																	
Exposure of the specimen																	
Cleaning the specimen																	
Do machining																	
Do machining																	
Get the Surface Roughness																	
Result Analysis																	
Report Writing																	
Submit draft and prepare slide presentation																	
Submit draft 2,3 and 4 and logbook																	
Final year 2 project presentation																	
Submit thesis report																	