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JUDUL: **EFFECTS OF CUTTING TOOL COATING ON SURFACE ROUGHNESS IN MACHINING PRE-HARDENED STEEL (P20)**

SESI PENGAJIAN: 2011/2012

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EFFECTS OF CUTTING TOOL COATING ON SURFACE ROUGHNESS IN MACHINING PRE-HARDENED STEEL (P20)

AINI RUSHDA BINTI MD DESA

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

Faculty of Manufacturing Engineering

Universiti Malaysia Pahang

JUNE 2012

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Manufacturing Engineering.

SUPERVISOR

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STUDENT'S DECLARATION

I declare that this thesis entitled Effects Of Cutting Tool Coating On Surface Roughness In Machining Pre-Hardened Steel (P20) is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature **: ....**

Name **:** AINI RUSHDA BINTI MD DESA

Date **:**

To my beloved parents

Mr Md Desa Bin Hasan

Madam Norlia binti Bakar

and

My fellow friends

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ABSTRACT

Quality of surface roughness is one of the challenges in the industry to produce high quality products. Cutting parameters and type of cutting tools are the factors that affect the quality of surface roughness. The purpose of this study is to examine the influences of different types of cutting tools coating and cutting parameters on the surface roughness. The cutting tools used are (TiN, TiCN and TiAlN). Taguchi method is used with three factors and three levels which is spindle speed (500. 1000, 1500) rpm, feed rate (500, 800, 1000) mm/min and diameter tool size (8, 10, 12) mm. The experimental results showed that, with larger diameter tool size the value of surface roughness will decrease. Same goes to spindle speed. When increasing spindle speed from (500-1500) rpm, the value of surface roughness also decreases. Different results surface roughness in feed rate, lower feed rate will produce better surface roughness. With suitable cutting parameters, TiAlN showed in decreasing surface roughness compare to the other two types of cutting tools. Confirmation test had verified that Taguchi design was successful in investigating the effect type of cutting tool coating on the surface roughness.

ABSTRAK

Kualiti kekasaran permukaan adalah salah satu cabaran dalam industri untuk menghasilkan produk yang berkualiti tinggi. Parameter mesin dan jenis salutan pada alat pemotong adalah faktor yang memberi kesan pada kekasaran permukaaan. Tujuan kajian ini adalah untuk mengkaji pengaruh jenis salutan pada alat pemotong dan parameter mesin terhadap kekasaran permukaan. Alat pemotong yang di gunakan ialah (TiN, TiCN, TiAlN). Kaedah Taguchi di gunakan dengan menggunakan tiga faktor dan tiga tahap bagi kelajuan penggumpar (500, 1000, 1500) rpm, kadar suapan (500, 800, 1000) mm/min dan saiz alat pemotong (8, 10, 12) mm. Keputusan eksperimen menunjukkan apabila menggunakan saiz alat pemotong yang besar, nilai kekasaran permukaan juga akan berkurang. Apabila kelajuan alat pemotong tinggi dari (500-1500) rpm, nilai kekasaran permukaan juga akan berkurang. Keputusan kekasaran permukaan berbeza pada kadar suapan, kadar suapan yang lebih rendah akan menghasilkan kekasaran permukaan yang lebih baik. Dengan menggunakan parameter yang sesuai, TiAlN menghasilkan kekasaran permukaan yang lebih baik berbanding menggunakan dua lagi jenis salutan alat pemotong. Ujian pengesahan yang di lakukan mengesahkan bahawa kaedah Taguchi yang digunakan berjaya dalam mengkaji kesan jenis salutan alat pemotong pada kekasaran alat pemotong.

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LIST OF ABBREVIATIONS

FYP	Final year project
TiN	Titanium Nitride
TiCN	Titanium Carbonitride
TiAlN	Titanium Aluminum Nitride
N	Spindle Speed
f_r	Feed Rate
C	Carbon
Si	Silicone
Mn	Mangan
Cr	Chromium
Mo	Molybdenum
ANOVA	Analysis Of Variance
v	Spindle Speed (rpm)
f	Feed Rate (mm/min)
d	Diameter Tool Size (mm)
DF	Degree of Freedom
Adj SS	Adjust Sum Square
Adj MS	Adjust Mean Square
F	Fisher's Ratio
P	Probabilty Value

CHAPTER 1

INTRODUCTION

1.1 PROJECT MOTIVATION

Surface finish is one of the important factor or requirement from the customer. The quality of the surface roughness is important to produce a precision mold. Without precision molds, there is no quality in producing a plastic product. This will adversely affect the industry. It is important to give a good characteristic of a part or product. A good characteristic is like a lower contact surface friction, light reflection, coating and resisting fatigue. Without lower surface roughness, all stated characteristics cannot be achieved. Therefore, a suitable cutting tool and cutting parameter is important to produce a better surface roughness.

1.2 PROJECT BACKGROUND

Milling machine is used to machine a solid material. In manual condition, milling machine can be used to machine any objects that are not axially symmetric. It also used to remove the unwanted material. Milling machine was widely used in many manufacturing industries including the aerospace and automotive sector. (Mike S.L et al, November 1998)

In this sector, quality plays an important role in increasing the productivity of the product. Surface finish or surface roughness is characteristic of the workpiece after machining. There are several factors that can affect the quality of surface roughness which is cutting speed, feed rate, depth of cut, type of tool and tool size (Mike S.L et al., November 1998).

Many research have been done to study the surface roughness. The studies used different methods towards the surface roughness. The methods are mathematical modeling and stylus profiler. By this method, the surface roughness can be measured.

1.3 PROBLEM STATEMENT

Several factors will affect the final result of surface roughness in CNC milling operation. The uncontrollable factor such as tool geometry, tool wear, chip loads and chip formation are the factor resulting in poor surface roughness. During the milling operation, chatter or vibration of the machine tool and wear will contribute to the damage of surface roughness.

The main point is stressed in this research is to choose a suitable cutting tool with a suitable parameter to produce a fine surface finish. Improper process parameters cause losses such as rapid tool wear and tool fracture besides the economic losses including spoiled workpiece or reduced surface quality (Gokkaya, H. et al. 2005).

The purpose of this research is to study the effect of the different type of cutting tools coating to the surface roughness together with the cutting parameters.

1.4 PROJECT OBJECTIVE

The objective of this research is to know the factors that affect surface roughness for machining the pre-hardened steel (P20). From the previous research had proved that different cutting tool coating produced different surface roughness. Beside that there are many machining parameters that are also contributing in the influenced of surface roughness.

These are the objectives of this research.

1. To study more about CNC milling machine
2. To analyze the effect of different type of cutting tools coating on the surface roughness
3. To determine the optimum cutting parameters in machining to produce better surface roughness.

1.5 PROJECT SCOPE

The scope of this project covers several issues from the milling machine, cutting tools coating used and the analysis.

1. **Different type of cutting tools coating.**
   Three types of cutting tool coating are used to determine the best type of cutting tool coating to produce the best surface roughness.
2. **Machining parameters.**
   Three types of machining parameters which is spindle speed, feed rate and diameter tool size is used to determine the optimal machining cutting for these parameters.
3. **Machining conditions.**
   Three level machining parameters are used which is high level, medium level and low level.

1.6 REPORT ORGANIZATION

This report is organized into five main chapters which is to explain the detailed information about the research.

1. **Introduction**

   This chapter discussed the information in term of background, problem statement, objectives, scopes and others. This chapter is important because it is used to give the general idea about this project.

2. **Literature review.**

   In this chapter, detailed information about this project is discussed. Some of the information is about milling machine, milling cutter, surface roughness and others.

3. **Methodology.**

   The design of experiments is discussed in this chapter. The method used is discussed in detail to show how the project is done.

4. **Result and discussions.**

   Result obtains from the experiment are shown in this chapter. The result is shown in term of table and graph. Then the data are analyzed and compare.

5. **Conclusion and recommendations.**

   This chapter summarized the overall of this project and determines whether the objectives of this project achievable or not. Recommendations for future study are also stated in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 MILLING MACHINE

Milling machine is a versatile machine. Milling machine not only machine flat surface but it also can perform other operations which are drilling, boring, reaming, threading and taping. Milling machine can be divided into two types known as horizontal milling machine and vertical milling machine.

Previously, milling machine was introduced by Eli Whiteney in the year of 1818. Milling machine was introduced in New Heaven Connecticut. (Meyers A.R et al, 2001).

2.1.1 Milling Process

In milling operation, the workpiece is fed pass through a rotating cutting tool that have been mounted on the spindle. The axis rotation of the tool is perpendicular to the feed direction. Milling cutter or cutting tool is the name that usually used in the industry for the tool used. Usually the plane surface is created through milling.

Many operations can be performed by using a milling machine. Each of these operations needs a suitable milling cutter in machining. It is important to use a suitable size of milling cutter because the size of milling cutter can also contribute to the machining surface finishing. The cutting tools with greater radius cause smaller surface roughness values (Tawfiq, 2008).

Before the machining operations were started, a suitable material and cutting tool must be chosen to withstand cycles of impact forces and thermal shocked (Marinov.V. 2011). Different types of milling operations are shown in Figure 2.1.

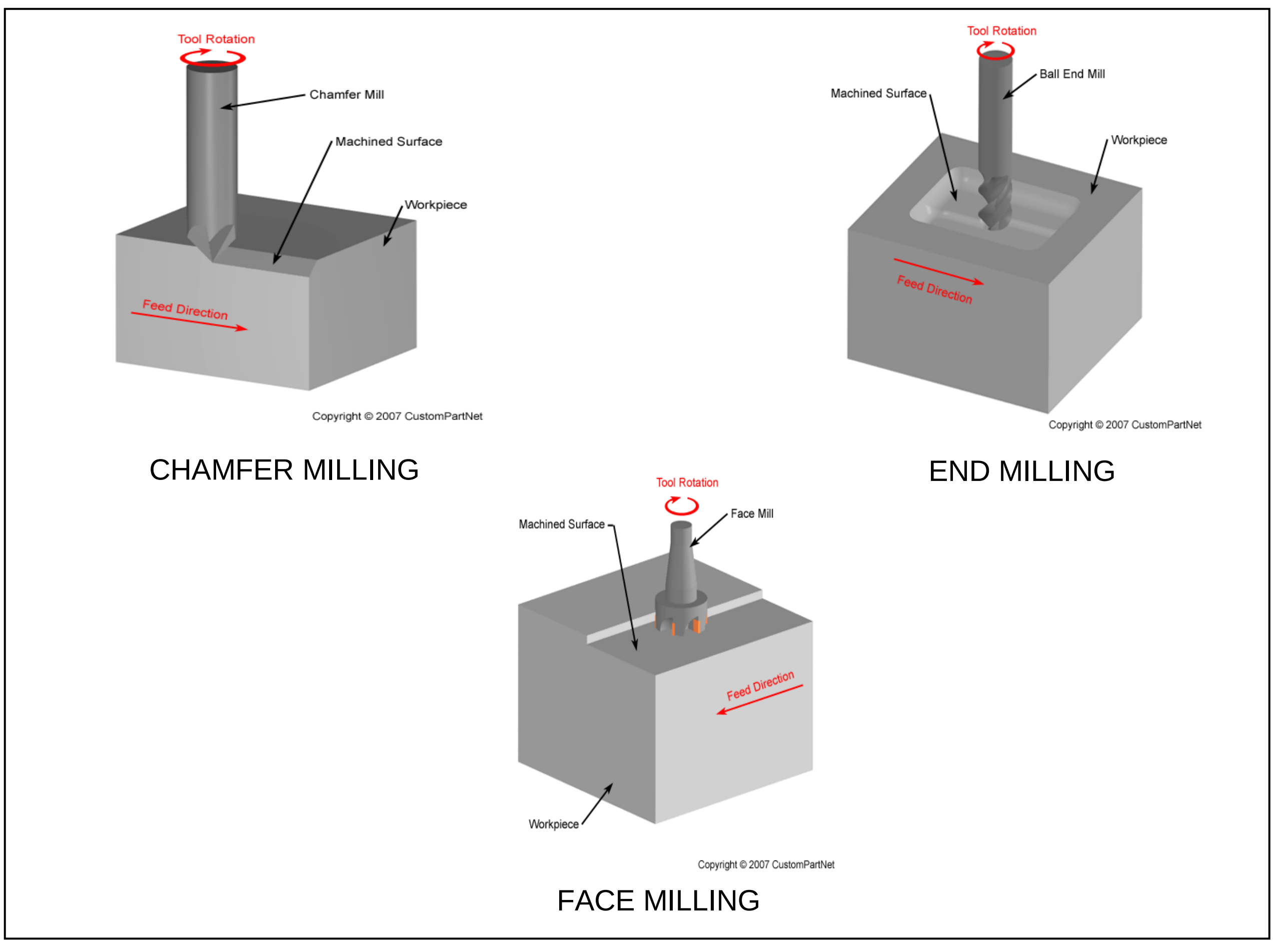

FIGURE 2.1: Milling Process

(http://www.custompartnet.com/wu/milling#design_rules)

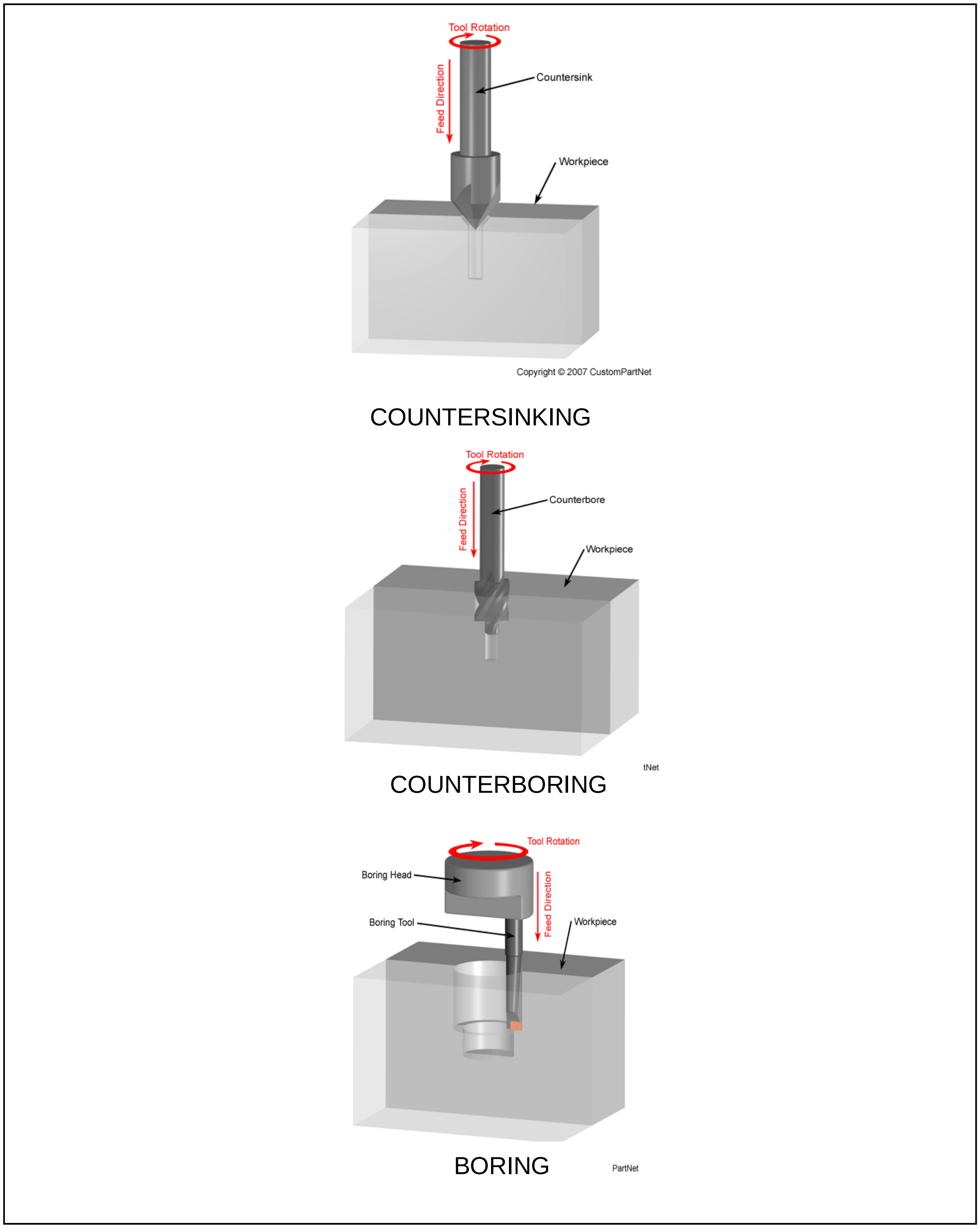

FIGURE 2.2: Milling Process

(http://www.custompartnet.com/wu/milling#design_rules)

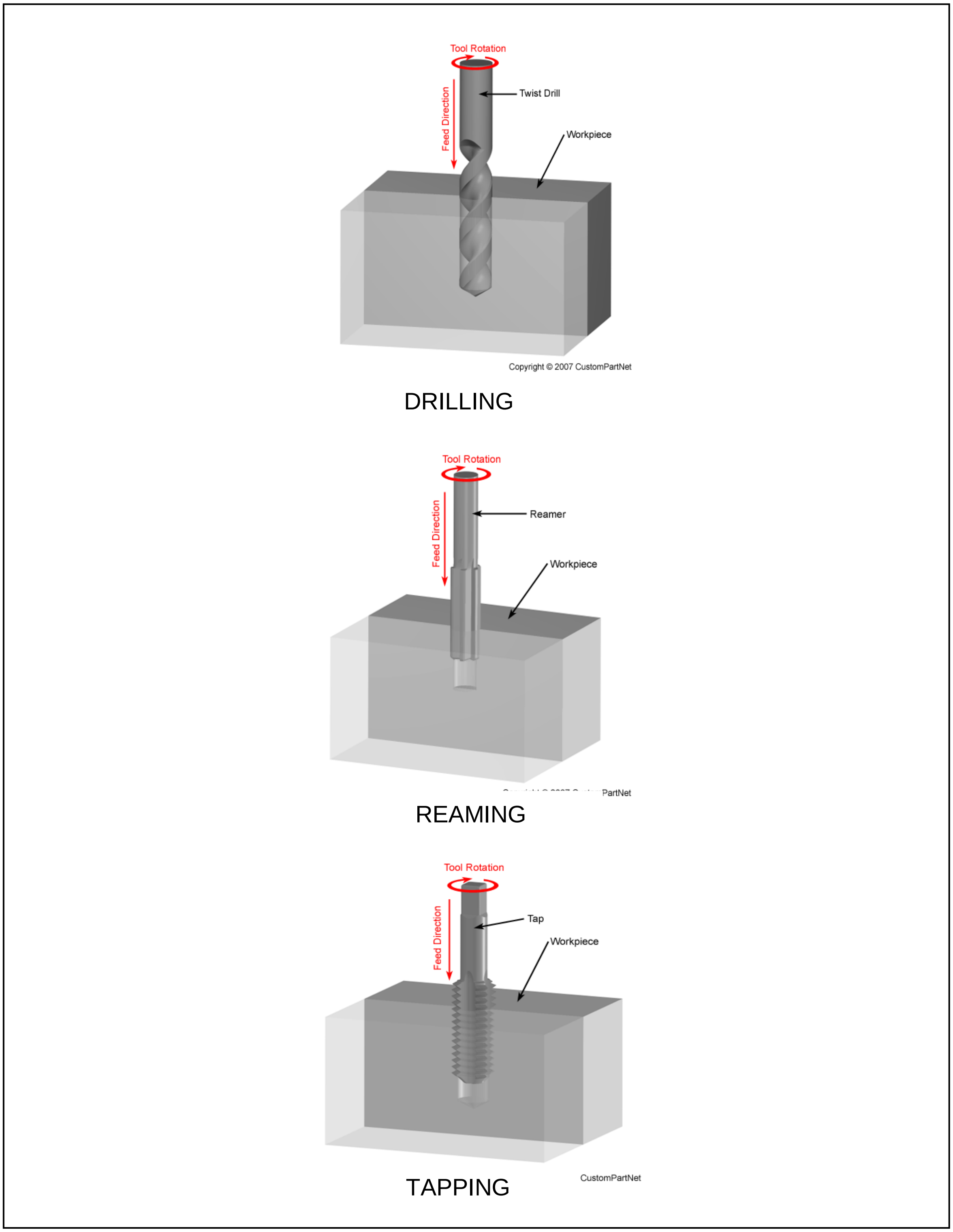

FIGURE 2.3: Milling Process

(http://www.custompartnet.com/wu/milling#design_rules)

2.1.2 MILLING PARAMETERS

In milling, there are several parameters should be considered before starting the machining operation. These parameters are selected due to workpiece material, type of cutting tool, cutting tool size and more. (http://www.custompartnet.com/wu/milling)

- Cutting speed -the velocity of the tool as it cuts the material.
- Cutting feed – the distance that the cutting tool cut the workpiece in one revolution of the spindle and tool. For a multipoint tool, the cutting feed is also equal to the feed per tooth.
- Spindle speed – the speed of spindle and tool in revolution per minute. The spindle speed is equal to the cutting speed divided by the circumference of the tool. The spindle is measured by revolution per minute (RPM).

$$N = \frac{v}{\pi D}$$

Where

N = spindle rotation speed (RPM)

v = cutting speed (in/min)

D = outside diameter of cutter (in)

- Feed rate – the speed of cutting tool toward the workpice as the tool makes a cut.

$$f_r = N n_t f$$

Where

f_r = feed rate (mm/min or in/min)

N = spindle rotation speed (RPM)

n_t = number of teeth

f = chip load (in/tooth or mm/tooth)

2.2 MILLING CUTTER

Milling cutters are one of the most important elements in milling process. Milling cutter helps in cutting different materials. Milling cutter is usually made of high speed steel.

2.2.1 End Mill

End mill is a type of milling cutter. Usually, end mill is a cutting tool that is used in an industrial milling application. It is a sharp milling cutter that will be rotated by the spindle. The cutter is a cylindrical tool with sharp teeth and there is a space between the teeth around the exterior. The space between the teeth is called flute and its function to remove all the chips form during machining from the work piece. Figure 2.2 shows the end mill nomenclature. The number of flutes that usually used is two and four flute end mill. The two flute end mill allows maximum space for chip ejection. It is generally used in the milling machine. Three flute end mill is used for general milling operation and its give excellent for slotting. End mill with 4, 5, 6, and 8 flutes can be used to improve the surface roughness if the feed rate remains constant. It is because a greater number of flutes reduces chip load. The end milling cutter can be categorized by the number of flutes, material, helix angle, and coating material. It also can be categorized by specific application and special geometry.

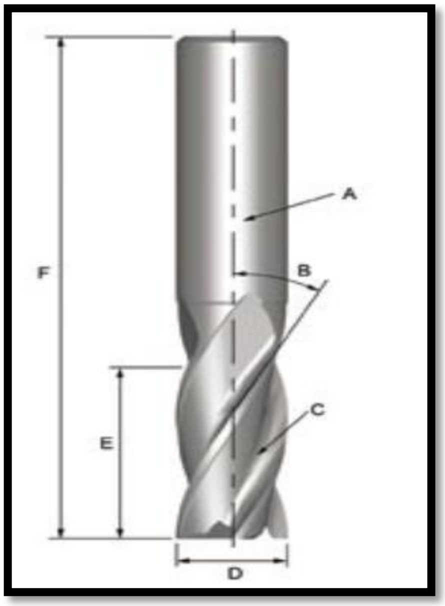

Figure 2.4: Nomenclature of End Mill

(Bray,S. 2004)

Where

A	Shank
B	Helix Angle
C	Flute
D	Outer Diameter
E	Cutting Length
F	overall Length

2.2.2 Coated Milling Cutter

During machining, milling cutter tends to wear. In order to avoid milling cutter to wear easily, coating is applied to milling cutter. The main function of coating is to reduce wear and friction. Titanium nitride (TiN), Titanium Carbonitride (TiCN), Titanium Aluminum Nitride (TiAlN), TiAlCrN, AlTiCrN and AlCrTiN (PVD coating) are types of coating usually used in industry. The advantages of applying coating at the tool are to increase tool life, reduce downtime, allow higher feed and speed rate and reduce tooling cost per job. Without correct tool choice, coating choice, the part material, tool rigidity, machine parameter will reduce the coating advantage as mention above (Park, H.O. 2012).

Titanium nitride (TiN) is produced in gold color. It is used for better tool life during machining mild steel, stainless steel and lnconel. The surface hardness of TiN is about 80 Rc. TiN has a very good corrosion resistance, heat transmission and excellent wear resistance. Characteristic of TiN is shown in the table below.

Table 2.1: Characterisctic Of TiN

Hardness	2800 HV
Thermal stability	550 °C / 1000F

Titanium carbonitride (TiCN) can be found in medium gray or bronze color. The hardness of TiCN is reaching 90 Rc. The benefits of using TiCN are improved surface roughness, improved wear resistance on abrasive, adhesive or material hard to machine. Depending on the application, coolant, machined parameter, and other condition, the speed and feed rate can be increased and tool life can be improved.

Table 2.2: Characterisctic of TiCN

Hardness	3000HV
Thermal stability	400 °C / 750 F

The color of Titanium Aluminum Nitride (TiAlN) is purple/black. The surface hardness of TiAlN is upper 80 Rc. Compared to TiN coating and TiCn coating, TiAlN coating produce less coefficient friction and the performance of TiAlN are good in machining abrasive and material hard to machine such as cast iron, aluminum alloy, tool steels and nickel alloy.

Table 2.3: Characterisctic of TiAlN

Hardness	2800HV
Thermal stability	750 / 1350 F

2.3 SURFACE ROUGHNESS

Surface roughness is the surface texture of the material after machining. In machining industry, quality plays an important role in order to meet the customer requirement. Quality is closely related to the surface roughness. There are several factors influencing the surface roughness such as cutting speed, feed rate and depth of cut (Tawfiq M. A et. al.,2008).

Gokkaya H. et al. (2005) state that surface roughness is affected by the cutting tool coating material, cutting speed and feed rate. The surface roughness can be measured by using a surface roughness tester. A good combination of cutting speed and feed rate can provide better surface qualities (Gokkaya, H. et. al, 2005).

A wide variety of surface textures are generated by machining process. Repetitive and/or random deviation from the ideal smooth surface forms the surface texture. These deviations are (Marinov,V. 2011).

- Roughness: small, finely spaced surface irregularities (micro irregularities)
- Waviness: surface irregularities of grater spacing (macro irregularities)
- Lay: predominant direction of surface texture

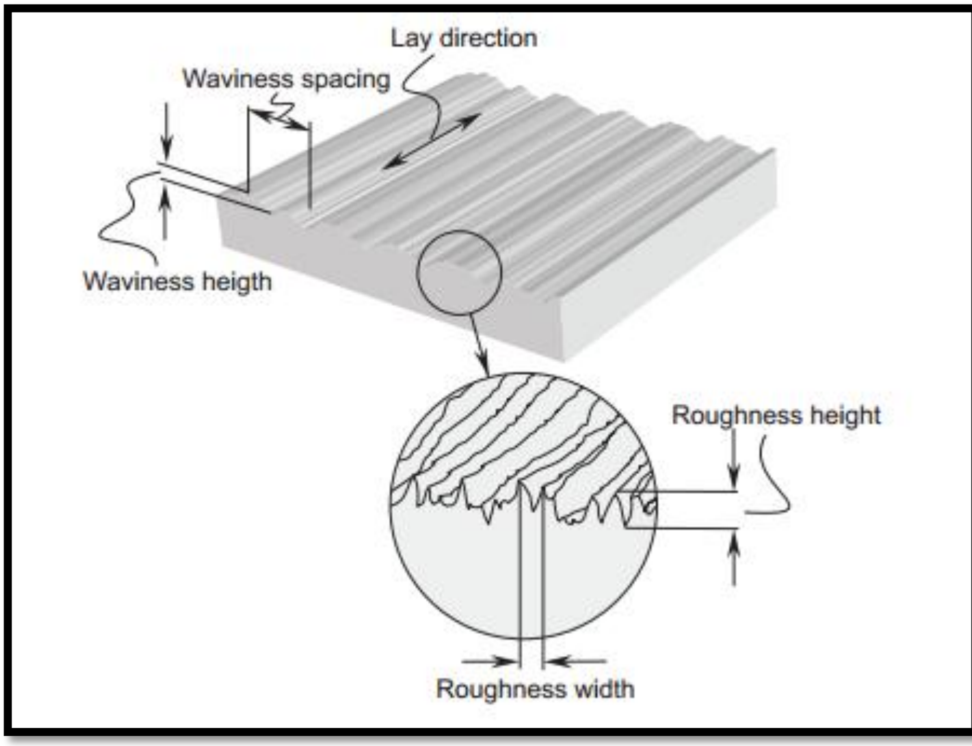

Figure 2.5: Elements of Machined Surface Texture

(Marinov.V, 2011)

Tawfiq M. A et. al. (2008) stated that surface roughness the arithmetic is R_a is known as arithmetic mean roughness or average roughness. R_a can be calculated by using the formula below:

$$Ra = \frac{1}{L}\int_0^L Y(x)\,dx$$

Where

L = the sampling length

y = the ordinate of the profile curve

Root mean square (rms) is the parameter that corresponds to R_a and R_q can be calculated by the formula below: (Tawfiq M. A et. al.,2008)

$$Ra\ or\ Rq = \sqrt{\left[\frac{1}{L}\int_0^L \left(Y(x)\right)^2\ dx\right]}$$

Where

L = the sampling length

y = the ordinate of the profile curve

2.4 TAGUCHI METHOD

Taguchi method or Taguchi design was developed by Dr. Genichi Taguchi (Park, S.H. et al.2008). Zhang, J.Z et al. (2007) stated that the application of this technique had become widespread in many US and European industry after the 1980s. By using Taguchi method multiple factor used in the experiment can be considered.

Thamizhmanii, S. et. al. (2006) stated that Taguchi method is statistical tool, adopted experimentally to investigate the influence of surface roughness by cutting parameters such as cutting speed, feed and depth of cut. The Taguchi process helps to select or to determine the optimum cutting conditions for the milling process.

There are three important points in this experiment which is factor, level and replication. The factor means the factor that affects the outcome. For the level means the value where the data are gathered and replication is referring to the gathering of results repeatedly in set of factor.

Park, S.H.et al.(2008) says that Design of Experiment (DOE) of Taguchi method had three steps in product design. The first step in product design is System design. This step is also known as primary design, functional design or concept design. System design step select the manufacturing process from the knowledge or related manufacturing technology. This is the time for the researcher to determine suitable working levels of the design factor (Zhang, J.Z et. al 2007).

The second step is parameter design. This step allows researchers to make a decision for the operating condition for each of the components. It concludes with the selection of proper orthogonal array, then run the experiment, analyzes data and come out with the result of optimum condition (Zhang, J.Z et. al 2007).

Tolerance design or tertiary design is the last design. In this step, it allows the researcher to investigate the tolerances of the process condition and sources of variability.

2.5 PRE-HARDENED STEEL

Pre-hardened P20 is usually used to make mold and die. For a mold designer, P20 is a good material and work well for a mold (Kazamer, O et al, 2007). In Japan PX5 is the new standard P20 (Britton, P.W. 2004). The benefit of using Pre hardened 20 is the uniform microstructure of the material give PX5 the best surface finish. P20 also has a good machinibility.

Pre-hardened steel (P20) have been used in many applications. One of the applications that used P20 is thermoplastic injection mold and extrusion mold. P20 also used as main parts of heavy-duty mold. The manufacturer of television casing, washing machine, and refrigerator inner casing and a water pot usually used P20.

Table 2.4: Machining Recommendations

Milling Carbide Tools & High Speed Steel Tools	Rough Milling	Finish Milling
Depth of cut (t) mm	min. 2	max. 2
Feed (s) mm/tooth	min. 0.2	max. 0.2
ISO Machining Group Cutting Speed (v) m/min. (Carbide Tools)	P30-P40 55-85	P10-P20 75-95
Cutting Speed (v) m/min. (High Speed Steel Tools)	10-20	15-30

(Szumera, J. 2003)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This section describes about the method used to start the research. The flow chart shows process occurs starting from the selection of the topic until the end of the research. Methodology is one of the important parts in order to achieve the research objective.

Figure 3.1 shows the flowchart of the overall process of this study.

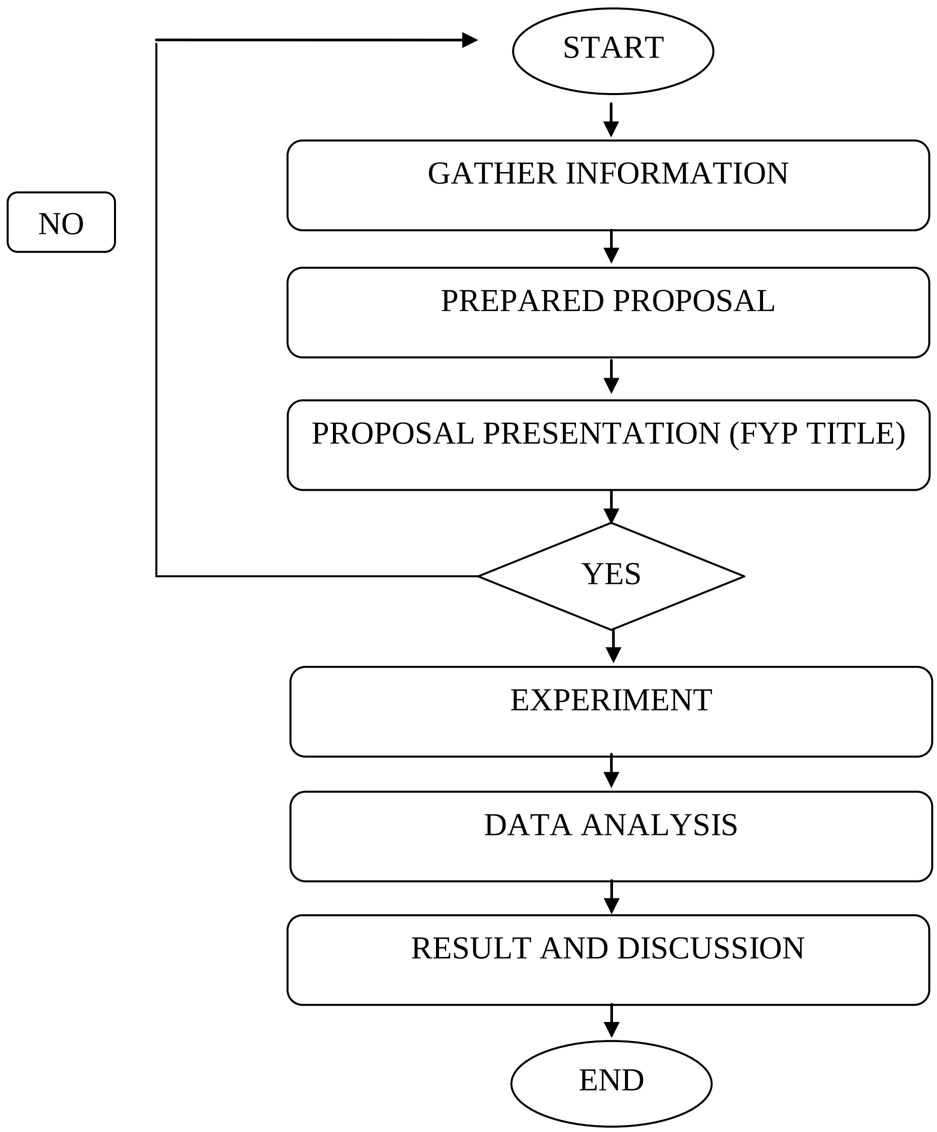

Figure 3.1: Flow Chart of overall methodology

3.2 MATERIAL SELECTION

A material used is pre-hardened steel (P20). Machining will be done on the material to investigate the effect of different cutting tools coating on the surface roughness. Table 3.1 is the typical chemical analysis.

Table 3.1: Typical Chemical Analysis

C (%)	Si (%)	Mn (%)	Cr (%)	Mo (%)
0.28-0.40	0.20-0.80	0.60-1.00	1.40-2.00	0.30-0.55

(Song et al. 2006)

Table 3.2 shows the physical properties for pre-hardened steel (P20). The density of pre-hardened steel P20, coefficient of thermal expansion, thermal conductivity and specific heat of P20 are put in the table according to the temperature. Different temperatures of pre-hardened steel have different physical properties.

Table 3.2: Physical Properties

Temperature	20 °C	200 °C	400 °C
Density(kg/m3)	7800	7750	7700
Thermal conductivity (J/m.s° C)	29.0	29.5	31.0
Specific Heat (J/kg °C)	460	-	-

http://www.westyorkssteel.com/p20.html

The modulus of elasticity below also put in the table according to temperature. Different temperatures of pre-hardened steel give different values of the modulus of elasticity.

Table 3.3: Physical Properties

Modulus elasticity	20 °C	200 °C	400 °C
Kp/mm2	20 900	20 400	18 900
N/mm2	205 000	200 000	185 000

http://www.westyorkssteel.com/p20.html

The table below shows the mechanical properties of pre-hardened steel (P20). The values of all the mechanical properties are taken under room temperature.

Table 3.4: Mechanical Properties

Tensile Strength	1000-1068 N/mm2
Yield Stress	861-930 N/mm2
Reduction of Area	45-50 %
Elongation	14-17 %

http://www.westyorkssteel.com/p20.html

3.3 Experiment

The experiment was run using NC milling machine. The experiment was also conducted according to Taguchi method. The overall design of experiments is shown in Figure 3.2. The factors used in this design of experiment are spindle speed, feed rate and diameter tool size. The value or level of each factor is taken from the manufacturer recommendations to machine pre-hardened steel (P20) with four flute high speed steel cutter.

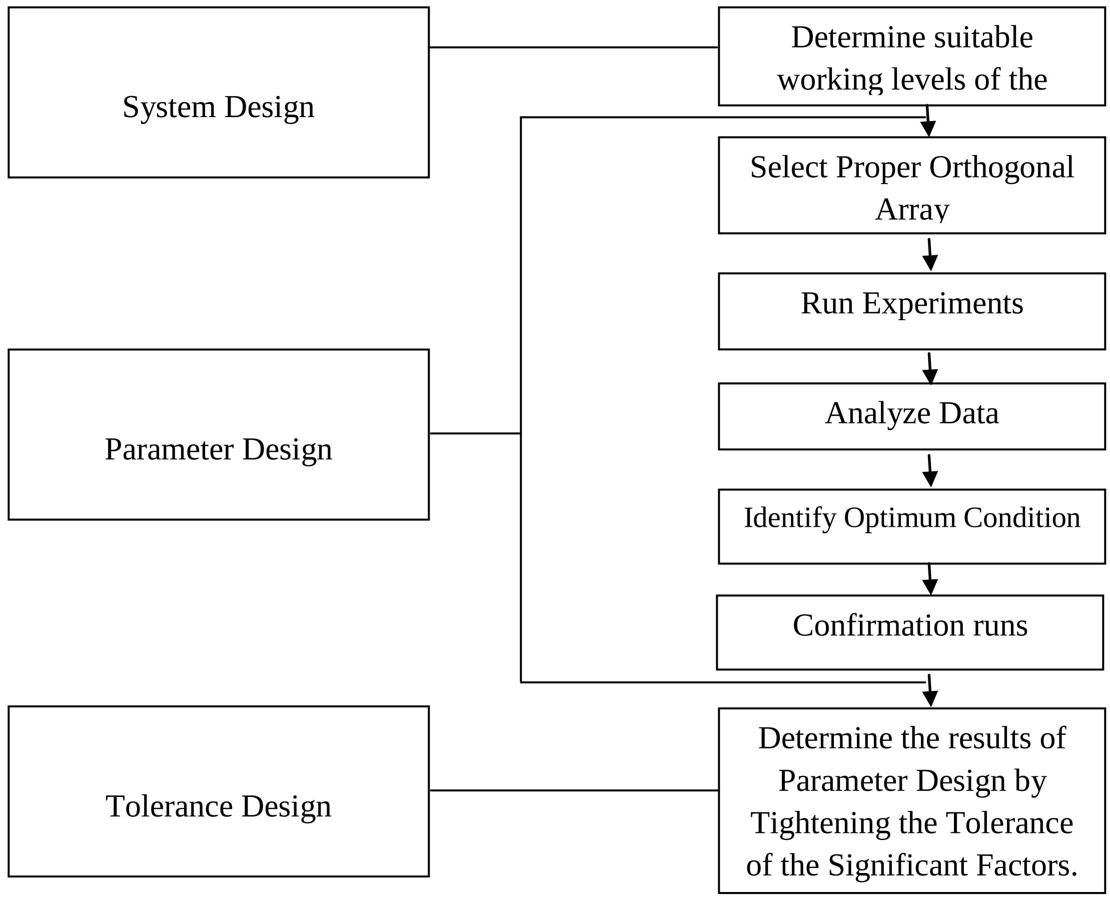

Figure 3.2: Taguchi Design Procedures

J.Z Zhang et. al (2007)

3.3.1 Determine suitable working levels of the design factors

After a suitable working level of the design factor are determined, proper orthogonal array are selected. There are three factors and three levels for each factor. The Table 3.5 below shows the factors and levels.

Table 3.5: Factors and Levels

Level / **Parameter**	Level 1	Level 2	Level 3
Spindle speed (rpm)	500	1000	1500
Feed rate (mm/min)	500	800	1000
Diameter tool (mm)	8	10	12

3.3.2 Selecting proper orthogonal array

A suitable orthogonal array is chosen according to the number of factor and level. In the design of the experiment, the possible combinations of factors and levels also known as full factorial combinations. But there is also disadvantages conducting full factorial. It is because conducting full factorial is costly and prohibitive. By using Taguchi method, the number of combinations can be obtained by using combination formula:

$$\text{Total number of combination} = (\text{number of levels})^{\text{number of factors}}$$

In this experiment, there are three factors and three levels. So, the number of combination is:

$$\text{Total number of combinations} = (3)^3 = 27$$

The L9 orthogonal array consists of 4 three level columns. Since the experiment only use three factors and three levels, one level from the array can be ignored. By using Minitab software, the L9 are generated. Table 3.6 shows the orthogonal array for L9.

Table 3.6: Orthogonal Array

Run	Cutting Parameter		
	v (rpm)	**f (mm/min)**	**d (mm)**
1	1500	500	12
2	1500	800	8
3	1000	500	10
4	1000	1000	8
5	1000	800	12
6	500	500	8
7	500	800	10
8	500	1000	12
9	1500	1000	10

3.3.3 Experiment

To run the experiment, five blocks of pre-hardened steel P20 are prepared. The size of P20 is 100mm x 100mm x 10 mm.

The experiment started with the face milling process. All the five blocks of pre-hardened steel are going to face using a face mill. The objective of this process is to make the face of workpiece are in flat surface. Started with titanium nitride (TiN) coated cutting tool, the experiment is run using three different sizes of diameter tool size. The workpiece is cut by slotting process. The cutting parameters are set first. The first parameters used is spindle speed 1500, feed rate 500 and the diameter tool size is 12 mm. Parameters are set according to the order of parameter value in an orthogonal array table. The experiment is continued with different parameters according to the order in an orthogonal array table. The experiment for the first coated cutting tool is repeated three times. The entire steps above are repeated to other two coated cutting tool which is titanium carbonitride (TiCN) and titanium aluminum nitride (TAlN). The experiments are repeated three times for each coated cutting tool.

After all the experiments are made with three types of coated cutting tool, the workpiece will be undergoing surface roughness test. At this stage, surface roughness tester is used. Cut of type used at the surface roughness tester is Gaussian. The measured length to measure the surface roughness is 20 mm with cut off wavelength is 0.8. The measurement speed is set to be 0.3 mm/s and magnification used is X 2K. Table 3.7 shows the summary of setting parameter at the surface roughness tester.

Table 3.7: Parameter setting Surface roughness tester (Surfcom 130a)

Cut off type	Gaussian
Measurement length	20mm
Cut of wave length	0.8
Measurement magnification	X 2K
Measurement speed	0.3 mm/s

When the surface roughness tester is set up, the block of workpiece is setup at the surface roughness tester. Adjust the stylus until it touches the workpiece. Measure button is pressed to measure the surface roughness. After the stylus move until 20 mm, the result will come out. The measurement is repeated two times to take the average surface roughness. Measurements step is also repeated for the other five blocks of work piece. The data then insert in the table according to its order.

Figure 3.3: Surface Roughness Tester (Surfcom 130a)

Figure 3.4: Measurement of Surface Roughness

3.3.4 Data Analysis

Data obtained from the experiment is then analyzed. The data obtained from the experiment are analyzed using Minitab software. From the Minitab software, the data are analyzed using regression analysis. From regression analysis, the correlation between dependent and independent variable can be obtained. From the analysis part shows that the correlation between the dependent variable and the independent variable is high. This can be proven by Rsq value. The data are also analyzed by Signal to noise analysis. From the signal to noise analysis, the major parameter that affects the surface roughness is obtained. Optimum cutting condition is also obtained from the signal to noise ratio analysis. S/N ratio analysis shows that diameter tool size plays an important role in order to get a better surface roughness.

3.3.5 Verification Test

The last step in Taguchi method is confirmation run. The objective of this confirmation run is to verify and predict the improvement of surface roughness. From signal to noise ratio result, the optimum combinations of cutting parameters are obtained. Cutting condition that used in confirmation run are the spindle speed with 1500 rpm, feed rate 800 mm/min and diameter tool size is 12mm. The result obtains from verification test were compared with prediction machining performance.

Table 3.8: Optimal Cutting Parameters

Factor	**Value**
Spindle Speed	1500 rpm
Feed Rate	800 mm/min
Diameter Tool Size	12 mm

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

The study was undertaken to investigate the effect of process parameters and type of cutting tools coating on surface roughness by milling operation. The operations have been done on solid material P20 (100x100x30)mm. Milling operation was carried out using various cutting parameters, feed rate and diameter tool size by using a different coated cutting tool. Machining data of surface roughness were tabulated accordingly. A Surface Roughness Tester measuring instrument was used to process the measured profile data. Surface roughnesses are measured from the surface roughness tester (Surfcom 130A). The measurement results are displayed digitally/graphically on the touch panel.

After the experiments were carried out on the three types of coated cutting tool, the specimen has been tested using surface roughness tester surfcom130A.Table 4.1, 4.2, 4.3 show the result of surface roughness for the three coated cutting tools.

Table 4.1: Surface Roughness Result and S/N Ratio for TiN

Run	Cutting Parameter			Average Ra (μm)	S/N Ratio (dB)
	v (rpm)	f (mm/min)	d (mm)		
1	1500	500	12	5.4098	-14.6637
2	1500	800	8	2.8268	-9.0260
3	1000	500	10	4.5055	-13.0749
4	1000	1000	8	4.0060	-12.0542
5	1000	800	12	6.6317	-16.4325
6	500	500	8	4.8242	-13.6684
7	500	800	10	4.0050	-12.0521
8	500	1000	12	5.5555	-14.8945
9	1500	1000	10	4.2153	-12.4966

Table 4.2: Surface Roughness result S/N Ratio for TiCN

Run	Cutting Parameter			Average Ra (μm)	S/N Ratio (dB)
	v (rpm)	f (mm/min)	d (mm)		
1	1500	500	12	2.1195	-3.26233
2	1500	800	8	5.5828	-14.9371
3	1000	500	10	4.4705	-13.0071
4	1000	1000	8	6.7857	-16.6319
5	1000	800	12	1.6333	-4.2615
6	500	500	8	5.9538	-15.4959
7	500	800	10	5.1253	-14.1944
8	500	1000	12	2.7995	-8.9416
9	1500	1000	10	3.3172	-10.4153

Table 4.3: Surface Roughness result S/N Ratio for TiAlN

Run	Cutting Parameter			Average Ra (μm)	S/N Ratio (dB)
	v (rpm)	f (mm/min)	d (mm)		
1	1500	500	12	1.7149	-4.68461
2	1500	800	8	4.0613	-12.1734
3	1000	500	10	3.9780	-11.9933
4	1000	1000	8	4.4918	-13.0485
5	1000	800	12	3.7948	-11.5839
6	500	500	8	5.3925	-14.6358
7	500	800	10	5.6442	-15.0320
8	500	1000	12	4.1459	-12.3523
9	1500	1000	10	4.1223	-12.3029

4.2 REGRESSION ANALYSIS

Regression analysis is used to determine the correlation between dependent and independent variable. The dependent variable is surface roughness and the independent variable is a parameter used such as spindle speed, feed rate and tool diameter size. Dr Mike S.L (1998) stated that, regression analysis can be used to analyze data from any of the major quantitative research designs such as casual-comparative, correctional, and experimental. Therefore, regression analysis will be useful to analyze the correlation between dependent and independent variables.

4.2.1 TiN Coated Cutting Tool

The regression equation used is

mean Ra = 10.7 - 0.000668 Spindle Speed + 0.00090 Feed Rate - 0.658 Tool Size

Table 4.4: Regression Analysis For TiN

Predictor	coef	SE Coef	T	P
Constant	10.671	1.571	6.79	0.001
Spindle speed	-0.0006677	0.0005035	-1.33	0.242
Feed rate	0.000899	0.001000	0.90	0.410
Tool size	-0.6581	0.1259	-5.23	0.003

S = 0.616611 R-Sq = 85.7% R-Sq(adj) = 77.1%

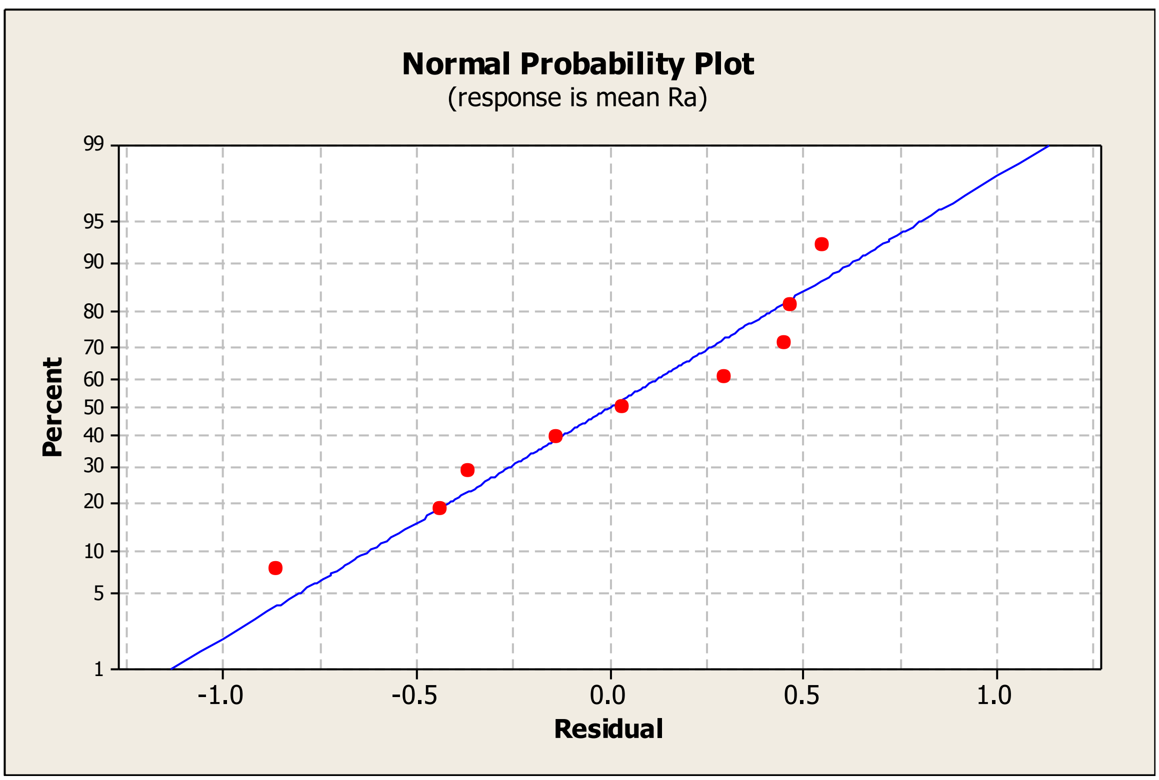

Figure 4.1: Normal Probability Plot for TiN

Based on the Table 4.4, the R-sq value is 85.7%. The dependent variable which is surface roughness (Ra) and independent variable which is spindle speed, feed rate and diameter tool size still have a correlation between each other. It shows that surface roughness highly depend on independent variables. To get a better surface roughness still depends on the independent variable like diameter tool size, spindle speed and feed rate. The distribution of data also close to the line, mean the correlation between dependent and independent variable is high.

4.2.2 TiCN Coated Cutting Tool

From Figure 4.2, it can be seen the correlation between a dependent variable which is surface roughness Ra to the independent variable which is spindle speed, feed rate and diameter size of cutter.

Mean Ra = 14.8 - 0.000953 Spindle Speed + 0.000202 Feed Rate - 0.981 Tool Size

Table 4.5: Regression Analysis for TiCN

Predictor	Coef	SE Coef	T	P
Constant	14.805	1.526	9.70	0.000
Spindle speed	-0.0009531	0.0004890	-1.95	0.109
Feed rate	0.0002024	0.0009715	0.21	0.843
Tool size	-0.9808	0.1223	-8.02	0.000

S = 0.598903 R-Sq = 93.2% R-Sq(adj) = 89.1%

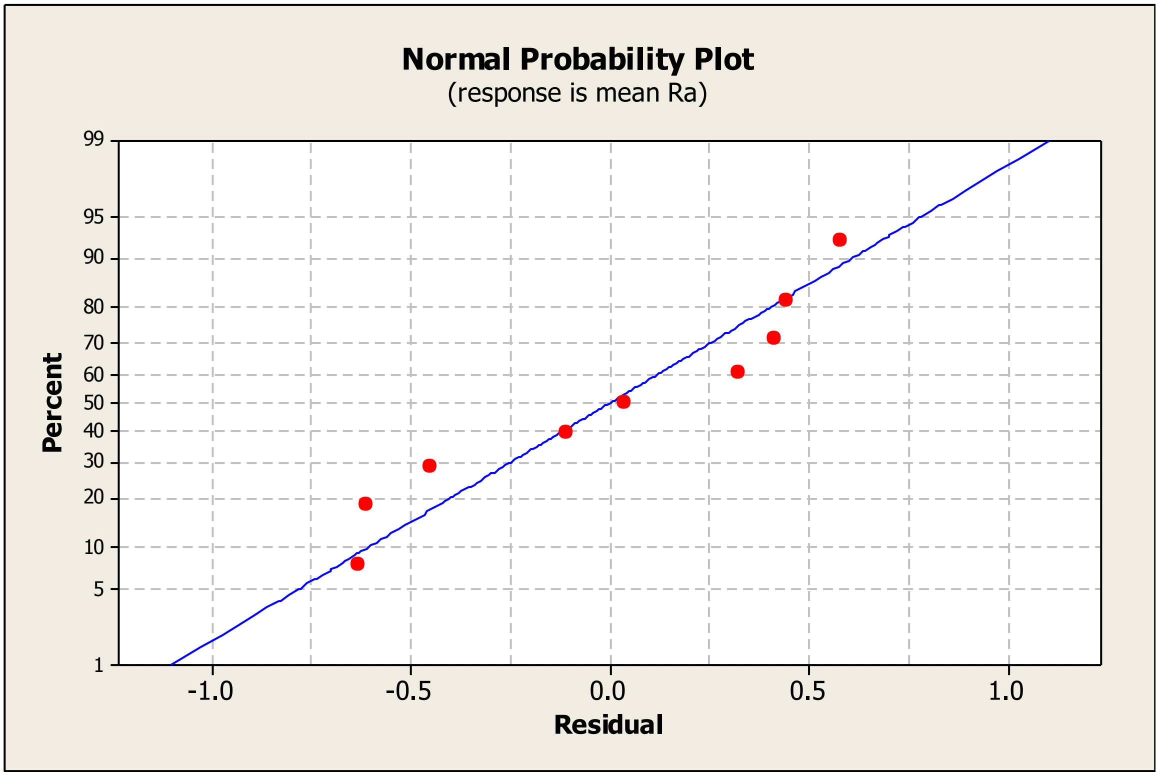

Figure 4.2: Normal Probability Plot for TiCN

R-Sq means the correlation between dependent and independent variable. The R-Sq value at the above is 93.2%. R-Sq value is close to 100%, that's mean that the correlation between surface roughness and parameter are closed together. From the figure, it can be seen that the data distribution closed to the line. The more data closed with the line, the higher relation between dependent and independent variable.

4.2.3 TiAlN Coated Cutting Tool

The equation of regression used is

Mean Ra = 8.54 - 0.00176 Spindle Speed + 0.00124 Feed Rate - 0.358 Tool Size

Table 4.6: Regression Analysis for TiAlN

Predictor	Coef	SE Coef	T	P
Constant	8.535	1.478	5.78	0.002
Spindle speed	-0.0017613	0.0004736	-3.72	0.014
Feed rate	0.0012401	0.0009409	1.32	0.245
Tool size	-0.3575	0.1184	-3.02	0.029

S = 0.580013   R-Sq = 83.2%   R-Sq(adj) = 73.1%

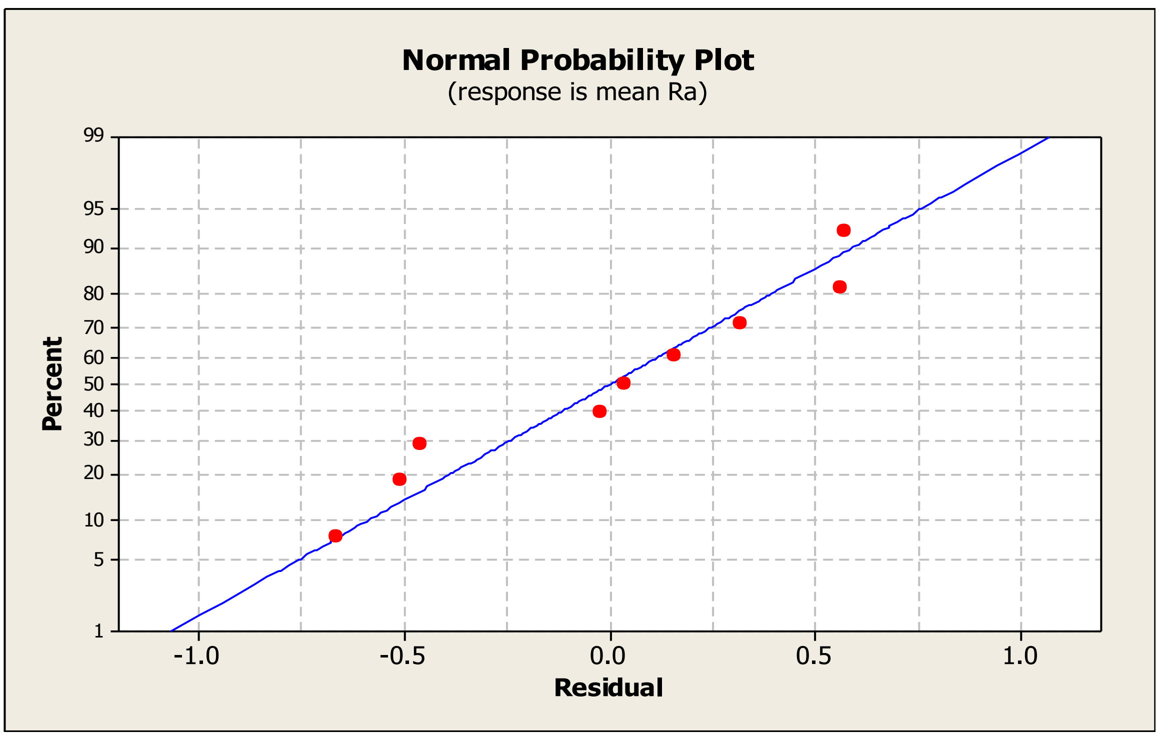

Figure 4.3: Normal Probability for TiAlN

From Table 4.6, the R-Sq value is 83.2%. The value is close to the 100%, means that the correlation between dependent and independent variable is high. Figure 4.3 shows the data distribution between a dependent variable which is surface roughness (Ra) and independent variable which is spindle speed, feed rate and diameter size of cutter. The distributions of data are highly with the line. This also shows that the relation between dependent and independent is highly related.

4.3 EFFECT OF PROCESS PARAMETERS ON SURFACE ROUGHNESS

4.3.1 TiN Coated Cutting Tool

Figure 4.4 below shows result of titanium nitride coating cutting tool.

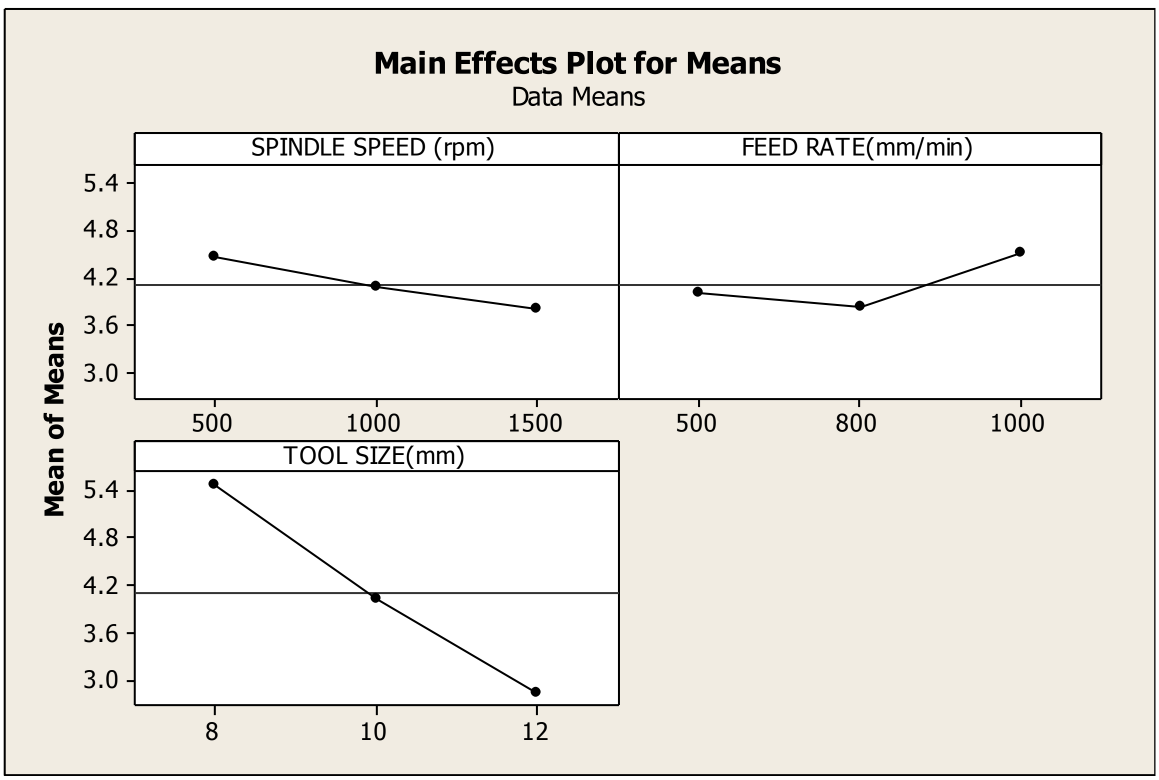

Figure 4.4: Mean Surface Roughness vs. Spindle Speed, Feed Rate, and Tool Size

Figure 4.4 shows an average surface roughness versus tool size, spindle speed and feed rate. From the figure above shows that surface roughness lower at higher diameter tool size. Average surface roughness increase as the diameter tool increase. Spindle speed also gives effect on surface roughness. The experimental shows surface roughness decrease as the spindle speed increase. Compare to feed rate, surface roughness increase as the feed rate increase. Higher feed rate will cause deterioration in surface quality. Increasing in feed rate also increase the chatter which result in higher surface roughness. These can be proved from the figure above.

4.3.2 TiCN Coated Cutting Tool

Figure 4.5 below shows result of titanium carbonitride coating cutting tool.

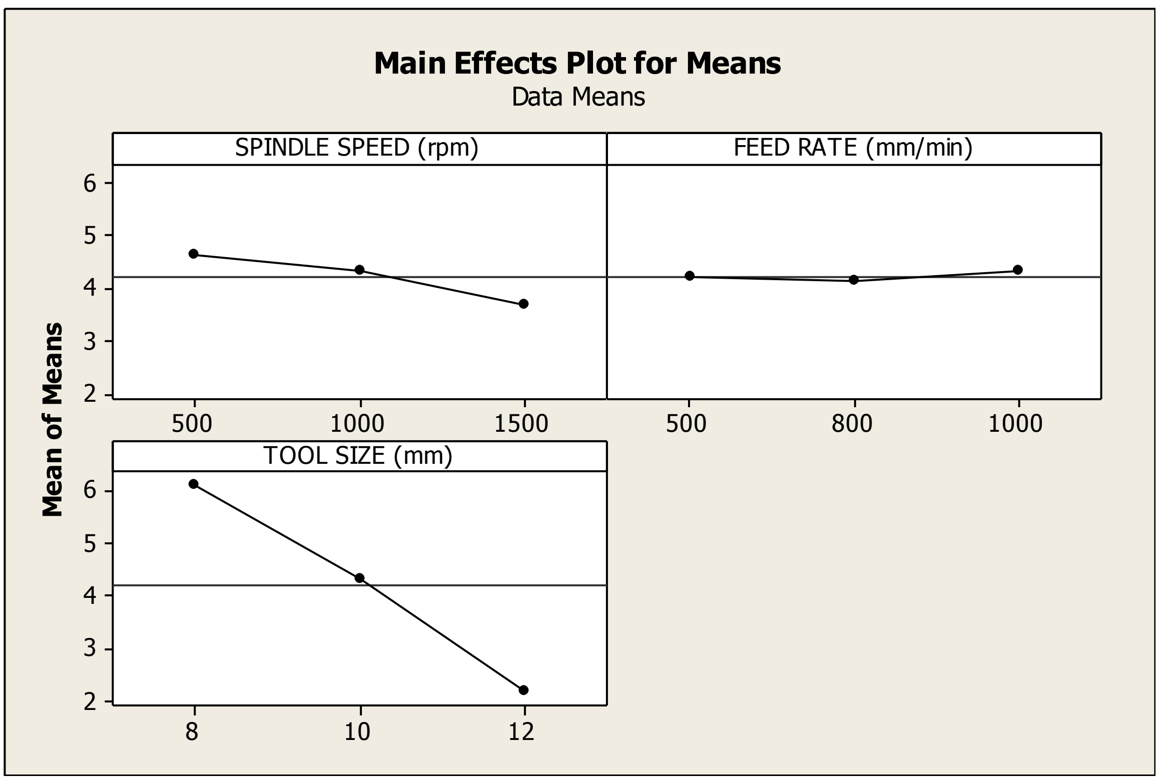

Figure 4.5: Mean Surface Roughness vs. Spindle Speed, Feed Rate, and Tool Size

From Figure 4.5 shows the influence of three parameters on the surface roughness. From the three parameters, diameter tool size gives major effect to the surface roughness. As the diameter tool size increase, surface roughness also decrease. The smaller surface roughness shows that surface roughness are fine. At diameter tool 12 mm shows smaller value of surface roughness compared to diameter tool 8 mm and 10 mm. Spindle speed and feed rate is not much effect the surface roughness compared to diameter tool size. As the spindle speed increase, surface roughness decrease. It shows that better surface roughness increase when the spindle speed increase. Compared to feed rate, surface roughness is lower at a lower feed rate. Surface roughness increase as the feed rate increase.

4.3.3 TiAlN Coated Cutting Tool

Figure 4.6 below shows result of titanium aluminum nitride coating cutting tool.

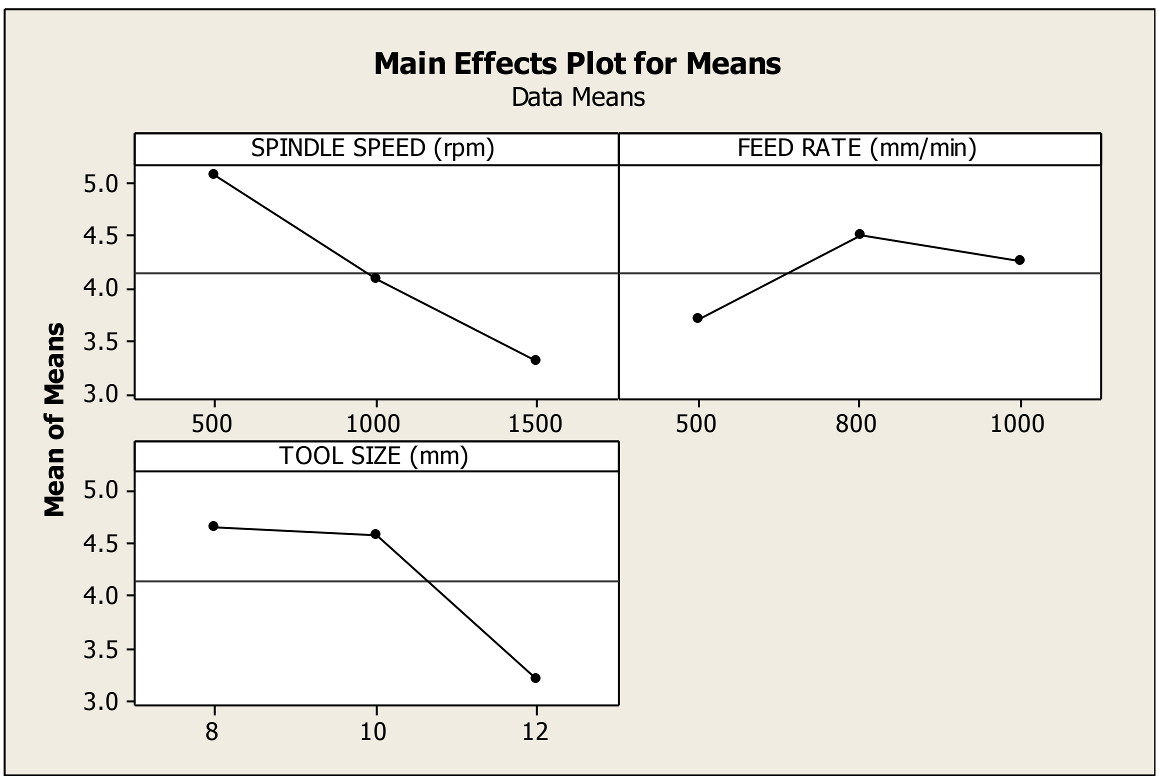

Figure 4.6: Mean Surface Roughness vs. Spindle Speed, Feed Rate, and Tool Size

Figure 4.6 shows the effect of three parameters on surface roughness from titanium aluminum nitride coating cutting tool. From the figure, tool size plays an important role in determining the surface roughness. Surface roughness decrease with increasing diameter size. These mean surface roughnesses are better with increasing diameter tool size. Value of surface roughness is higher at smaller diameter cutting tool. Second parameter effect surface roughness is spindle speed. The result shows average surface roughness decrease with increasing spindle speed. Smaller value average surface roughness shows a better surface roughness. It is different with feed rate. Average surface roughness increase with increasing feed rate. The slower feed rate will give better surface roughness.

4.4 ANALYSIS OF SIGNAL TO NOISE (S/N) RATIO

In Taguchi method, the term signal represents the desirable value and noise undesirable value. S/N ratio is used to measure the quality characteristics which deviate from the desired value. S/N ratio can be calculated using equation suggested by Taguchi method. For this experiment, a characteristic that is used is smaller the better. This means the smaller value of surface roughness is the better surface roughness. The equation used for S/N ratio as below:

$$S/N = -10 \log \left(\frac{1}{r} Ra^2 \right)$$

Where:

Ra: average surface roughness

The S/N ratio of all parameters is calculated by averaging the S/N ratio. Table 4.7, 4.8 and 4.9 shows the response of S/N ratio of surface roughness according on the type of coating cutting tool.

4.4.1 TiN Coated Cutting Tool

Table 4.7: Response Table for S/N Ratios (TiN)

Level	S/N Ratios for v (dB)	S/N Ratios for f (dB)	S/N Ratios for d (dB)
1	-12.931	-11.732	-14.739
2	-11.330	-10.956	-12.052
3	-11.265	-12.838	-8.734
Δ(max-min)	1.666	1.882	6.005
Rank	3	2	1

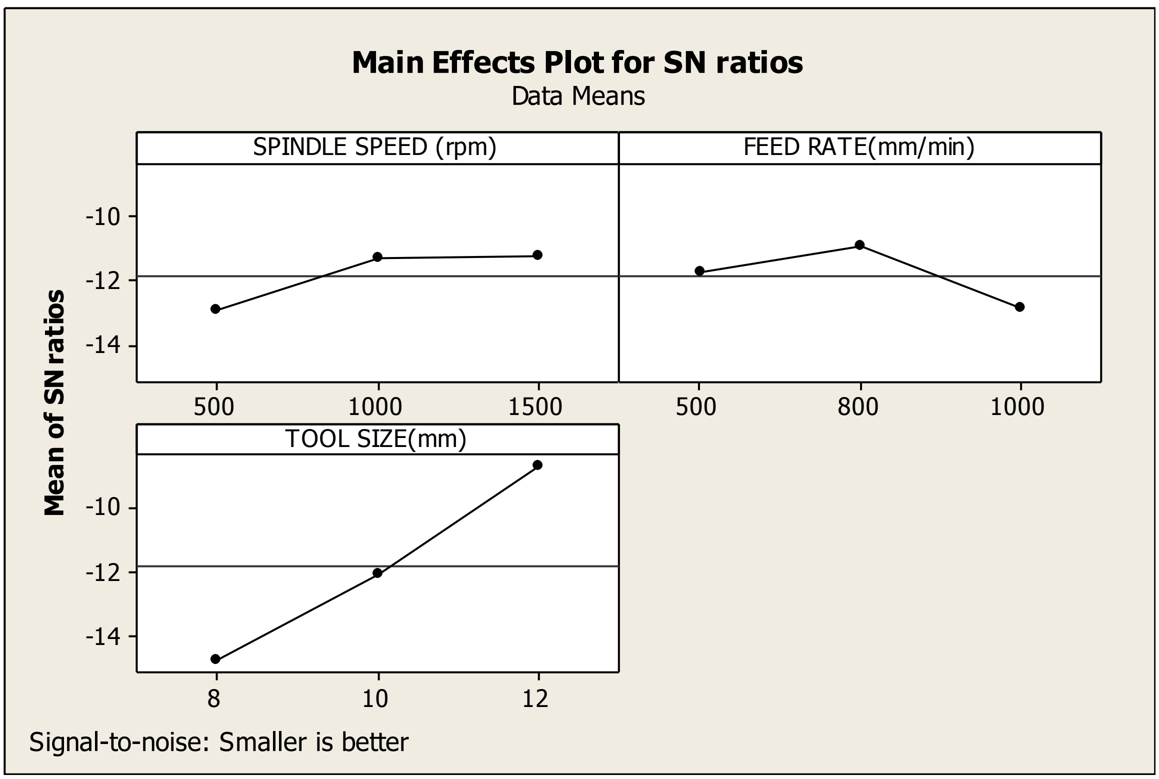

Figure 4.7: S/N Ratios vs. Spindle Speed, Feed Rate, and Tool Size (TiN)

Based on Table 4.7 shows the diameter tool size plays an important role in determining surface roughness. These prove by the different value between maximum values of S/N ratio to the minimum value of S/N ratio. Compared to the other parameter, the difference between maximum and minimum value is high. Feed rate is the second parameter that affects surface roughness. The difference between maximum and minimum value is 1.882dB and the last parameter is spindle speed. From the graph, the optimum cutting condition can be figured for the present experiment. The optimum cutting conditions for spindle speed is 1500 rpm, feed rate 800mm/min and diameter tool size is 12mm.

4.4.2 TiCN Coated CuttingTool

Table 4.8: Response Table for S/N Ratios (TiCN)

Level	**S/N Ratios for v (dB)**	**S/N Ratios for f (dB)**	**S/N Ratios for d (dB)**
1	-12.877	-11.676	-15.688
2	-11.300	-11.131	-12.539
3	-10.626	-11.996	-6.576
Δ(max-min)	2.252	0.865	9.112
Rank	2	3	1

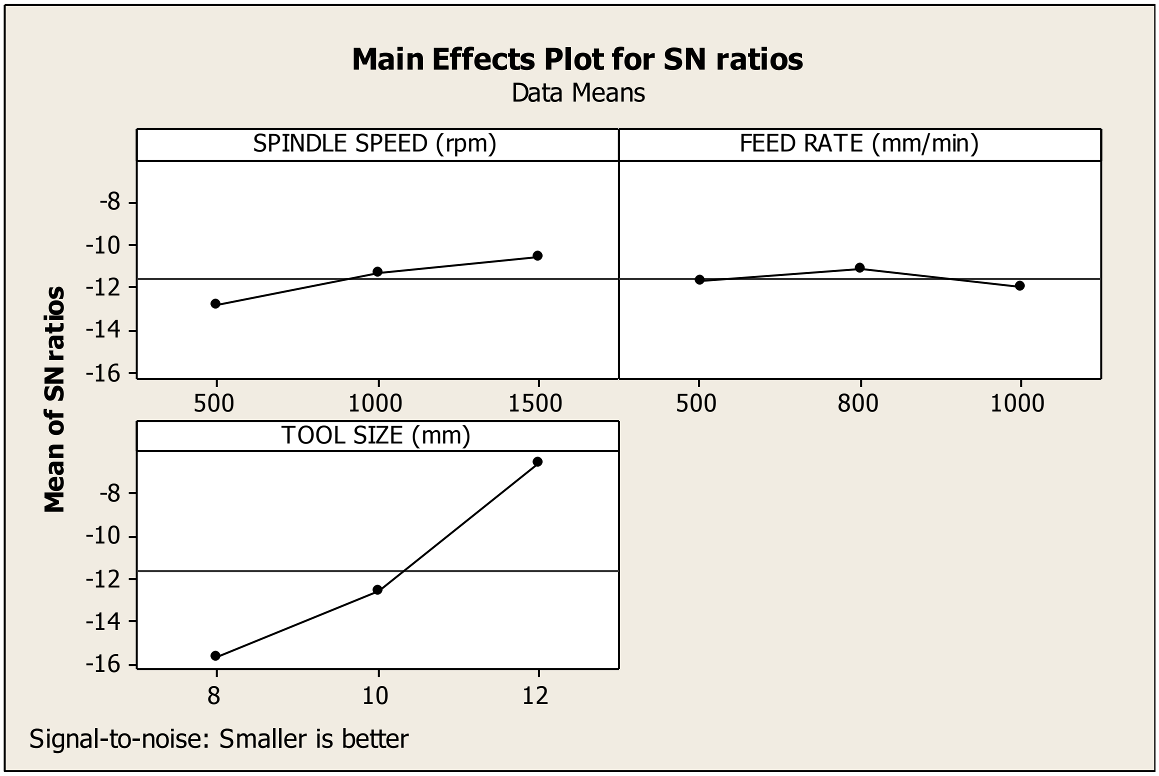

Figure 4.8: S/N Ratios vs. Spindle Speed, Feed Rate, and Tool Size (TiCN)

From Figure 4.8 above, it is seen that the variation of mean S/N ratio at lower and higher feed rate not much different with 0.865 dB. Therefore, for the present experiment, high feed rate will be chosen as an optimum condition for the productivity reason. For the spindle speed, it is shown that the difference between lower and higher is 2.252 dB. Its mean that spindle contribute in surface roughness effect. Compared from the three parameters, diameter tool size gives a major contribution to the surface roughness with 9.112 dB difference between lower and higher diameter tool size.

4.4.3 TiAlN Coated Cutting Tool

Table 4.9: Response Table for S/N Ratios (TiAlN)

Level	S/N Ratios for v (dB)	S/N Ratios for f (dB)	S/N Ratios for d (dB)
1	-14.007	-10.438	-13.286
2	-12.209	-12.930	-13.109
3	-9.720	-12.568	-9.540
Δ(max-min)	4.286	2.492	3.746
Rank	1	3	2

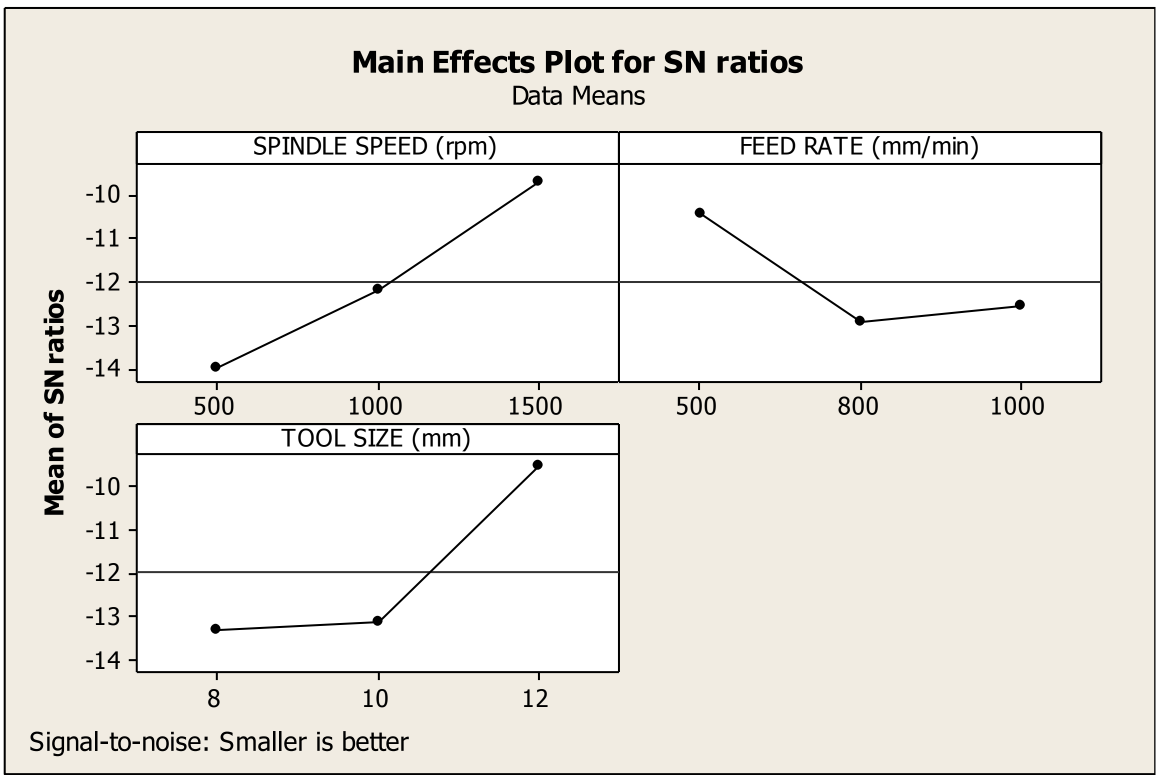

Figure 4.9: S/N Ratios vs. Spindle Speed, Feed Rate, and Tool Size (TiAlN)

Figure 4.9 above shows a graph of mean of S/N ratio versus machine parameter. The result for titanium aluminum nitride coating cutting tool give spindle as the major effect on surface roughness. This can be proved from the table above. The differences between maximum mean S/N ratios with a lower mean S/N ratio larger with 4.286 dB compared to tool size is 3.76 dB and feed rate is 2.492 dB. From this result, the optimum spindle speed, diameter tool size and feed rate can be chosen for future experiment.

4.5 ANALYSIS OF VARIANCE (ANOVA)

In statistic, analysis of variance (ANOVA) is a statistical model which observed variables in a particular variable. Analysis of variance is a technique to analyze data from the experiment in which one or more response. In this study, ANOVA is carried out to investigate the effect of process parameter on the surface roughness.

The General linear model is one of the analysis of variance techniques. It can be used for both crossed and nested factors, models in which one or more of the variables is random rather than fixed, and when quantitative factors are to be combined with categorical ones. The designs that can be analyzed with General linear model procedure are partially nested designs, repeated measures experiments, split plots, and many others.

An analysis of variance can be written as a linear model. The equation can predict the response as a linear function of parameters and design variables. Sahoo, A.K (2011) show the general equation of the linear model is

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots\ldots + \beta_p X_{ip} + \epsilon_i$$

Where:

Y_i is response for ith observation

β_p is unknown parameter to be estimated

Analysis of variance tests is carried out by comparing independent mean square. After the general linear analysis is done, the result shows the F value and P value. This is called analysis of variance of F static and also known as ANOVA F static. The F static test has the form:

$$F = \frac{\text{Between Group Estimate Of Variance}}{\text{Within Group Estimate Of Variance}}$$

Under the null hypothesis, large F values direct to reject the null hypothesis. If the F value at least as large as the one observed given that the null hypothesis is true is called significance probability value (or P value). Guidelines for the P value are if $P \leq 0.01$, it shows that the difference is highly significance. For the P values > 0.01 but p value ≤ 0.0, its mean that there has difference of significant. For P value, $P \geq 0.10$, it shows that the difference has no significance **(**Park, S.H et al. 2008).

4.5.1 TiN Coated Tool

Table 4.10: Analysis Of Variance for Mean Ra, Using Adjusted Ss for Tests (TiN)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	0.6730	0.6730	0.3365	0.48	0.674
Feed Rate	2	0.7768	0.7768	0.3884	0.56	0.641
Tool Size	2	10.4322	10.4322	5.2161	7.51	0.117
Error	2	1.3885	1.3885	0.6942		
Total	8	13.2706				

S = 0.833208   R-Sq = 89.54%   R-Sq(adj) = 58.15%

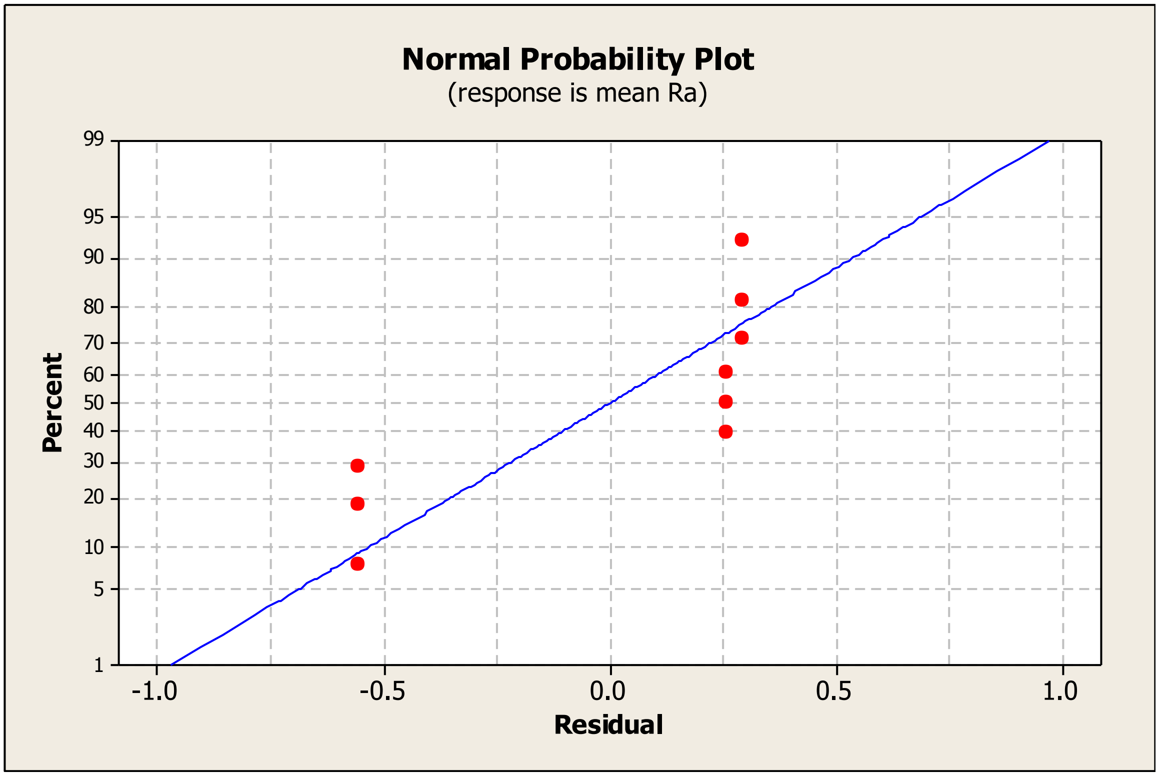

Figure 4.10: Normal Probability Plot (TiN)

From the three parameters, diameter tool size shows the lowest P value which is 0.117. The other two factors which are spindle speed and feed rate are 0.641 and 0.647. All the three values are not significant to the surface roughness which is the P value higher than 0.10. The reason for this occur because, there will be noise factor affect the surface roughness during machining. The example of noise factor is tool chatter, vibration and other factor that can't be control.

4.5.2 TiCN Coated Tool

Table 4.11: Analysis Of Variance for Mean Ra, Using Adjusted Ss for Tests (TiCN)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	1.4056	1.4056	0.7028	0.85	0.542
Feed Rate	2	0.0538	0.0538	0.0269	0.03	0.969
Tool Size	2	23.1391	23.1391	11.5695	13.92	0.067
Error	2	1.6618	1.6618	0.8309		
Total	8	26.2603				

S = 0.911545 R-Sq = 93.67% R-Sq(adj) = 74.69%

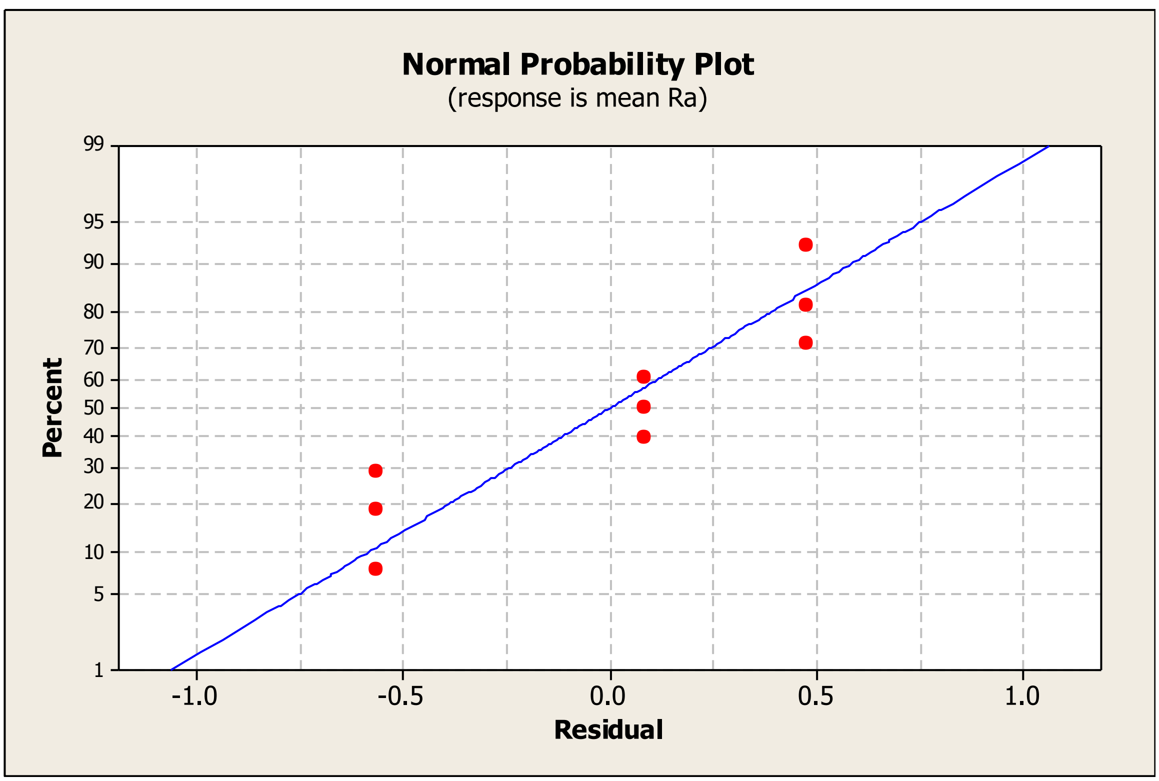

Figure 4.11: Normal Probability Plot (TiCN)

Based on the table above, the probability value or P value for diameter tool size is the most significant. The P value of diameter tool size is 0.067 where the P value in the range of P values > 0.01 but p value ≤ 0.0. It means that there is difference in significant. Feed rate and spindle give higher P value. P value for spindle speed is 0.542 and P value for the feed rate is 0.969. The P value for both spindle speed and feed rate is in the range of P ≥ 0.10. It is mean that both factor spindle speed and feed rate are insignificant to the surface roughness. Increasing feed rate will cause tool wear. Tool wear is one of the factors that influence the surface roughness. Therefore, tool wear is a noise factor that can't be control.

4.5.3 TiAlN Coated Tool

Table 4.12: Analysis Of Variance for Mean Ra, Using Adjusted Ss for Tests (TiAlN)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	4.6704	4.6704	2.3352	11.99	0.077
Feed Rate	2	1.0205	1.0205	0.5103	2.62	0.276
Tool Size	2	3.9072	3.9072	1.9536	10.03	0.091
Error	2	0.3894	0.3894	0.1947		
Total	8	9.9874				

S = 0.441229   R-Sq = 96.10%   R-Sq(adj) = 84.41%

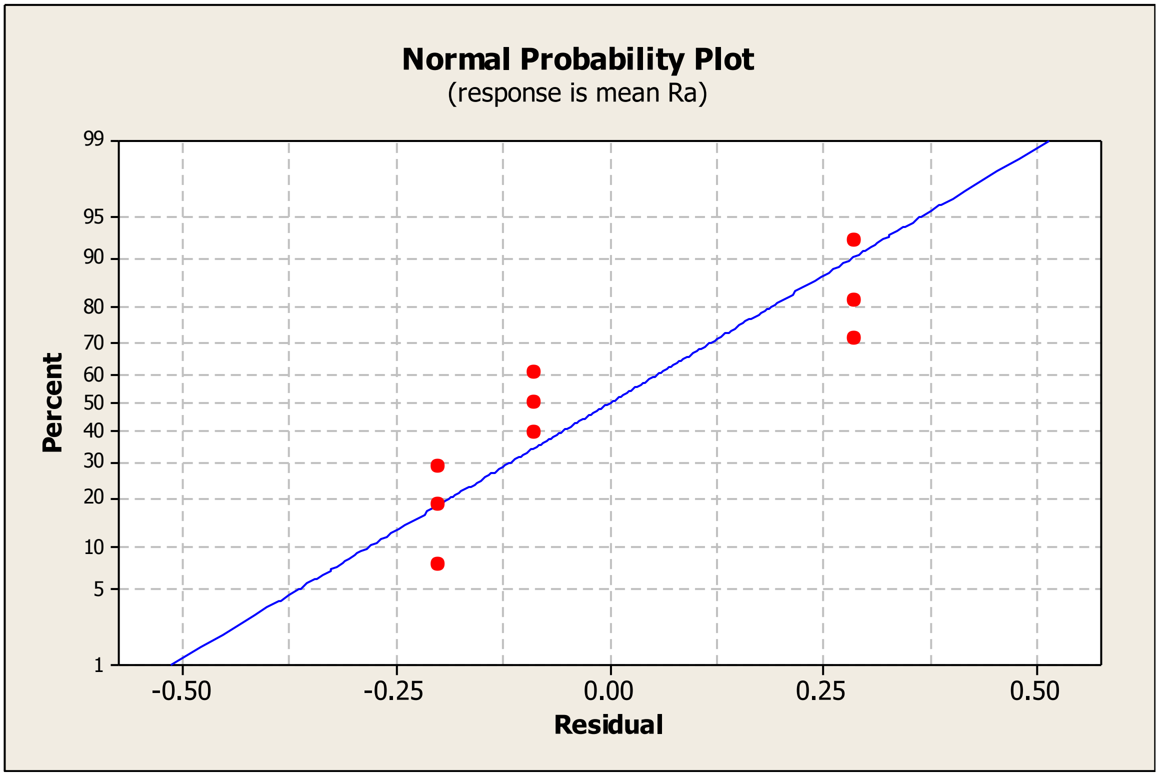

Figure 4.12: Normal Probabilty Plot (TiAlN)

For TiAlN coating cutting tool, spindle speed gives larger F static value with 11.99 and the probability value, (P value) is 0.077. For diameter tool size, F static test value for diameter tool size is 10.03 with P value 0.91. Both spindle speed and diameter tool size have range of P value within P values > 0.01 but p value ≤ 0.0. This shows that both factors have different significant but still affect surface roughness. Feed rate gives the largest P value in this experiment. The P value of feed rate is 0.276. It means that feed rate is insignificant to the surface roughness. By increasing feed rate, the surface roughness increase. Higher feed rate will bring the cutting tool to transverse the workpiece so rapidly and cause damage to the surface quality.

4.6 VERIFICATION TEST

The last step in Taguchi method is to verify and predict the improvement of surface roughness. From the S/N ratio analysis, the optimum combination cutting parameters are obtained. The combination of optimal cutting parameters should produce a better or improved surface roughness (smallest Ra).

4.6.1 TiN Coated Tool

Table 4.13: Result of the Verification Test for Surface Roughness (TiN)

	Initial Cutting Parameters	Optimal Cutting Parameter	
		Prediction	Experiment
Level	v = 1500 rpm f = 500 mm/min d = 12mm	v = 1500 rpm f =800 mm/min d = 12mm	v = 1500 rpm f =800 mm/min d = 12mm
Surface Roughness (µm)	5.409833	2.41261	3.1318
S/N ratio (dB)	-14.6637	-7.6497	-9.9159
Improvement of S/N Ratio	4.7478		

Based on the Table 4.13, surface roughness obtain from confirmation run is 3.1318 µm. By using S/N ratio equation from Sahoo.A.K et al. (2010), the S/N ratio is -9.9159 dB. Compared with S/N ratio initial cutting parameter, there is increasing in S/N ratio. Based on Table 4.13, the improvement of S/N ratio from initial cutting parameter to optimal cutting parameter is 13.4405. This can be proved by verification test and the surface roughness decrease 1.7274 times from initial cutting parameter. The surface roughness improves at optimal cutting parameter.

4.6.2 TiCN Coated Tool

Table 4.14: Result of the Verification Test for Surface Roughness (TiCN)

	Initial Cutting Parameters	**Optimal Cutting Parameter**	
		Prediction	**Experiment**
Level	v = 1500 rpm f = 500 mm/min d = 12mm	v = 1500 rpm f =800 mm/min d = 12mm	v = 1500 rpm f =800 mm/min d = 12mm
Surface Roughness (µm)	2.1195	1.64130	2.1035
S/N Ratio (dB)	-6.5246	-4.3037	-6.4588
Improvement of S/N Ratio	0.0329		

According to the Table 4.14, surface roughness obtain after confirmation run is 2.1035 µm. S/N ratio is calculated using S/N ratio equation from Sahoo.A.K et al. (2010). The S/N ratio obtains after calculation is -6.4588 dB. The S/N ratio shows an increase between optimal cutting parameter and initial cutting parameters. From the table, the improvement of surface roughness calculated between initial cutting parameter and optimal cutting parameter. Improvement of S/N ratio is 0.0329. This improvement can be proof when the value of surface roughness is decrease with 1.0076 times.

4.6.3 TiAlN Coated Tool

Table 4.15: Result of the Verification Test for Surface Roughness (TiAlN)

	Initial Cutting Parameters	**Optimal Cutting Parameter**	
		Prediction	**Experiment**
Level	v = 1500 rpm f = 500 mm/min d = 12mm	v = 1500 rpm f =800 mm/min d = 12mm	v = 1500 rpm f =800 mm/min d = 12mm
Surface Roughness (μm)	1.71487	1.91410	1.106
S/N Ratio (dB)	-4.68461	-5.6392	-1.2232
Improvement of S/N Ratio	3.46141		

Table 4.15 shows the value of surface roughness for optimal cutting parameter and initial cutting parameter. After confirmation run had been done, surface roughness obtain is 1.106. From the value of surface roughness, S/N ratio is calculated using S/N ratio equation from Sahoo.A.K et al. (2010). S/N ratio is -1.2232 using optimal cutting parameters. Due to Table 4.15, the S/N ration decrease from initial cutting parameters to optimal cutting parameters. This shows the improvement of S/N ration by 3.46141. The evidence is from verification result, which the value of surface roughness decreases by 1.4783 times. The surface roughness improves using the optimal cutting parameter.

4.7 EFFECT CUTTING TOOLS COATING

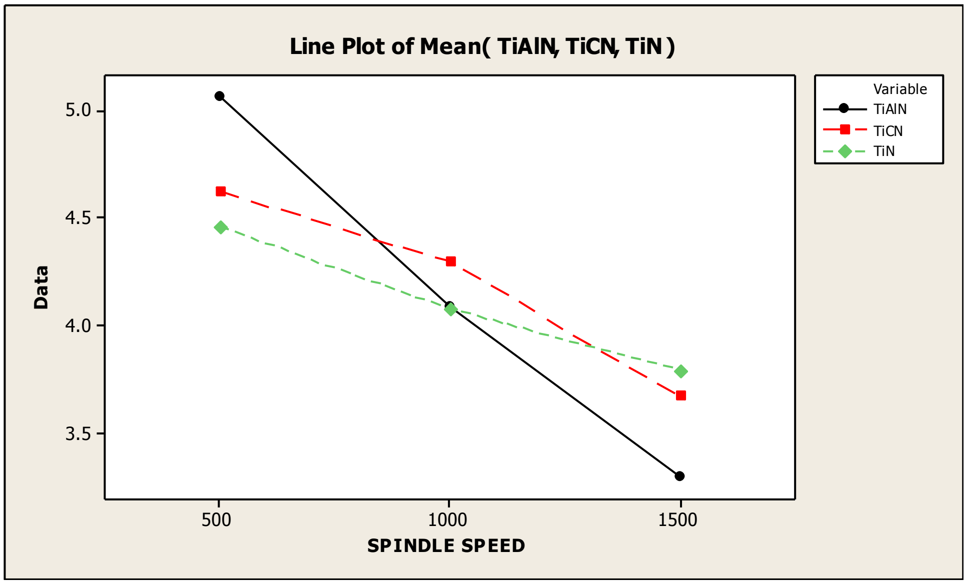

Figure 4.13: Surface Roughness Vs Spindle Speed (TiN, TiCN, TiAlN)

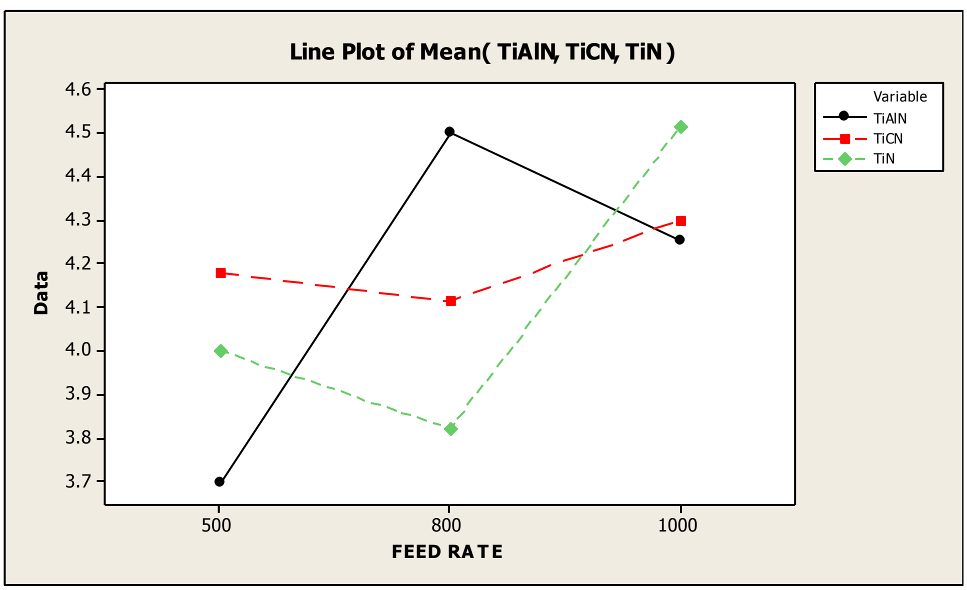

Figure 4.14: Graph Of Surface Roughness Vs Feed Rate (TiN, TiCN, TiAlN)

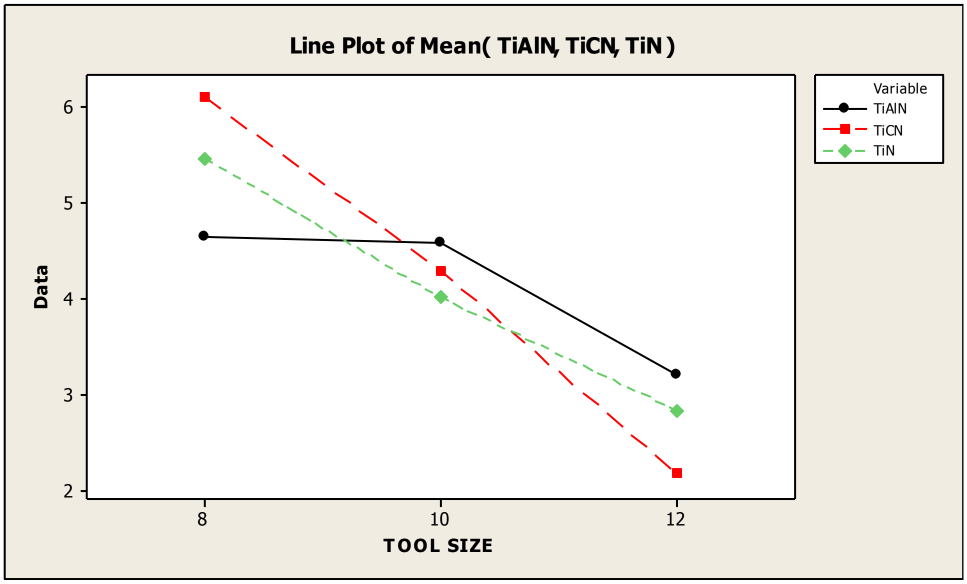

Figure 4.15: Graph of Surface Roughness Vs Tool Size (TiN, TiCN, TiAlN)

Figure 4.13, 4.14 and 4.15 show the relationship between surface roughness for different type of coating cutting tool to the spindle speed, feed rate and diameter tool size. Based on the Figure 4.13, 4.14 and 4.15, according to the coating types, the best surface roughness obtained from Titanium Aluminum Nitride. The next best coated cutting tool is TiCN then TiN. Based on the hardness of coated cutting tool, TiAlN is the harders. The second hardest is TiCN and followed with TiN. With higher hardness, produce better surface roughness. From here, it can conclude that TiAlN produce a better surface roughness comparable to Titanium Nitride and Titanium Carbonitride. Higher hardness will slow the tool wear. So, it can produce better surface compare to the other two types of coating. TiAlN coating also known to be better from the other coating such as TiN and TiCN in protecting tools. It also has a higher coefficient of friction and thermal conductivity compare with the other two cutting tool which led to a better surface roughness.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter summarizes all the data and answer the objective of the research. The data are obtained from the research will be compared with previous studied.

5.2 CONCLUSION

The effects of coated type of cutter and machine parameter on pre-hardened steel (P20) workpiece were investigated using Taguchi method. The result of experimental work can be summarized as follows:

- According to types of cutting tool coated, the best surface roughness obtains with TiAlN, followed by TiCN and TiN.
- From the experimental result, it can be proved that as the diameter tool size increase the value of the surface roughness decrease. The experimental result showed that the value of surface roughness is lower at a lower feed rate and higher at lower spindle speed.

- The effect of machine parameters on the surface roughness has been evaluated using Taguchi orthogonal array. The optimal cutting parameters to minimize surface roughness have been obtained.
- From the S/N ratio table, it was shown that diameter tool size is most factored that influenced the surface roughness. As the diameter tool size increase will produce a better surface roughness.
- To achieve good surface roughness on pre-hardened steel (P20), higher spindle speed, lower feed rate and larger diameter tool size were preferred. Using TiAlN with combination optimal cutting parameter is reported in producing good surface roughness.

5.3 RECOMMENDATION FOR FUTURE STUDY

From the conclusion, some recommendations are suggested in order to get a good surface roughness for pre-hardened steel (P20). From the results prove that lower diameter tool effect the surface roughness. For future research or experiment, it is recommended using larger diameter tool. Next recommendation is feed rate. Lower feed rate contributes in producing lower surface roughness. From the experimental result and previous study had reported that to get a good surface roughness, lower feed rate is highly recommended. The spindle speed is also one of the factors determine the surface roughness. Higher spindle speed will produce a good surface roughness. The evidence can get from the result of experimentation. It is proving that higher spindle speed produces good surface roughness. It is recommended to use higher spindle speed. Good combinations of cutting parameters produce lower surface roughness. Type of coated for cutting tools also contribute to get the good surface roughness. High hardness and higher thermal stability give lower surface roughness. With the correct choice of coating cutting tool and best combination optimal cutting tools produce good surface roughness.

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