PARAMETER OPTIMIZATION OF A CYLINDRICAL GRINDING OPERATION FOR THE HIGH QUALITY OF SURFACE FINISH

MOHD ASRUL BIN ABU BAKAR

BACHELOR OF ENGINEERING

UNIVERSITI MALAYSIA PAHANG

2010

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL: **PARAMETER OPTIMIZATION OF A CYLINDRICAL GRINDINGOPERATION FOR THE HIGH QUALITY OF SURFACE FINISH**

SESI PENGAJIAN: **2010/2011**

Saya, **MOHD ASRUL BIN ABU BAKAR_(880106-11-5139)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana/Doktor Falsafah)~~* ini disimpan di Perpustakaan Universiti Malaysia Pahang dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang.
2. Perpustakaan Universiti Malaysia Pahang dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[✓]	TIDAK TERHAD	

Disahkan oleh

________________________	________________________
(TANDATANGAN PENULIS)	(TANDATANGAN PENYELIA)

Alamat Tetap:
Kampung Gong Terap,
Chalok,
21450 Setiu,
Terengganu Darul Iman

MR KUMARAN KADIRGAMA

Tarikh: **06 DISEMBER 2010** Tarikh: **06 DISEMBER 2010**

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.
◆ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertai bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjans Muda (PSM).

UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled “Parameter Optimization of a Cylindrical Grinding Operation for the High Quality of Surface Finish” is written by Mohd Asrul Bin Abu Bakar. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

MR HADI BIN ABDUL SALAAM Signature

Examiner

PARAMETER OPTIMIZATION OF A CYLINDRICAL GRINDING OPERATION FOR THE HIGH QUALITY OF SURFACE FINISH

MOHD ASRUL BIN ABU BAKAR

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DISEMBER 2010

SUPERVISOR'S DECLARATION

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

Signature:

Name of Supervisor: MR. KUMARAN KADIRGAMA

Position: LECTURER

Date: 06 DECEMBER 2010

STUDENT’S DECLARATION

I declare that this thesis entitled “*Parameter Optimization of a Cylindrical Grinding Operation for The high Quality of Surface Finish*” is my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature:
Name : MOHD ASRUL BIN ABU BAKAR
ID Number: ME07065
Date: 06 DECEMBER 2010

DEDICATION

To my Beloved Parents

Abu Bakar Bin Yaacob
Marizan Binti Mamat

ACKNOWLEDGEMENTS

I would like to express profound gratitude to my supervisor Mr. Kumaran Kadirgama for his invaluable support, germinal ideas, encouragement and continuous guidance in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for engineering and technology, and his belief that a bachelor degree program is only a start of a life-long learning experience. I am also highly thankful to Mr. Rosdi Bin Daud, my ex-supervisor for his valuable guidance and suggestions throughout this study.

I am grateful for the cooperation of UMP staff especially to Mr Aziha bin Abdul Aziz, Assistance Instructor Engineer and Mr. Mohd Adib bin Mohd Amin, Instructor Engineer who helped me in machine usage in mechanical lab. Secondly for Madam Nor Sa'adah Bt Nor Azmi, the Assistance Instructor Engineer in Metallurgy lab who teach me in using Perthometer M1. Moreover, I would like to acknowledge all of my friends especially Abd. Faiz Bin Muhammad, Mohd Muhyiddin Bin Ibrahim and Mohd Nazmi Bin Nordin offer me their helping hand in my project.

I acknowledge my sincere indebtedness and gratitude to my parents and fiancee for their love, dream and sacrifice throughout my life. I acknowledge the sincerity of my brother and sister for their sacrifice, patience, and understanding that were inevitable to make this work possible. Finally, I wish to express my appreciation to my friends in manufacturing course, who share their love and experience with me. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

ABSTRACT

The most important parameter describing surface integrity is surface roughness. In the manufacturing industry, surface must be within certain limits of roughness. Therefore, measuring surface roughness is vital to quality control of machining workpiece. This thesis presents Parameter Optimization of a Cylindrical Grinding Operation for The high Quality of Surface Finish. The objective of this study is to perform experiment using Cylindrical Grinding Machine. The other purpose is to investigate the effect of parameters parameter which are work speed, diameter of workpiece and depth of cut that influences the surface roughness on carbon steel (AISI 1042). Besides that, the aim of this study is to determine optimum cylindrical grinding process parameters using the Full Factorial method. The surface roughness were measured using Perthometer S2 and evaluated according to the change of the grinding conditions. Mathematical model was developed to predict the surface roughness using the experimental results. With the help by STATISTICA software, ANOVA have been used for this purpose and an optimal condition has been found out. As a result, the diameter of workpiece , gave more significant effect to the surface roughness compare to the other two parameters which are the work speed, and depth of cut.

ABSTRAK

Parameter yang paling penting yang menggambarkan integriti permukaan kekasaran permukaan. Dalam industri perkilangan, permukaan harus berada dalam batas-batas tertentu kekasaran. Oleh kerana itu, pengukuran kekasaran permukaan sangat penting untuk mengawal bahan kerja mesin. Tesis ini mempersembahkan Optimasi Parameter dari Gerinder Silinder Operasi untuk Kualiti Permukaan yang Tinggi. Tujuan dari pembelajaran ini adalah untuk melakukan percubaan menggunakan Gerinder Silinder Mesin . Tujuan lain adalah untuk mengetahui pengaruh parameter seperti kelajuan kerja, diameter bahan kerja dan kedalaman potong yang mempengaruhi kekasaran permukaan pada besi berkarbon (AISI 1042). Selain itu, tujuan dari pembelajaran ini adalah untuk menentukan parameter yang optimum proses gerinda silinder dengan menggunakan kaedah Faktorial Penuh. Kekasaran permukaan diukur dengan menggunakan Perthometer S2 dan dinilai sesuai dengan perubahan keadaan penggilingan. Model matematik dibangunkan untuk meramalkan kekasaran permukaan menggunakan hasil eksperimen. Dengan bantuan oleh perisian Statistica, ANOVA telah digunakan untuk tujuan ini dan keadaan yang optimum telah dijumpai. Akibatnya, diameter bahan kerja, lebih memberikan pengaruh yang signifikan terhadap kekasaran permukaan berbanding dengan dua parameter lain yang kelajuan kerja, dan kedalaman potongan.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this chapter, overview of this project was told. Problems occurred in industrial environment such as in costly, production rate and time were stated in this chapter. Besides that, the objectives and scopes regarding to this project were told.

1.2 OVERVIEW

Demand are being placed on the automobile, aerospace, and medical component industries to produce stronger, lighter, precision parts. This in return is forcing improvement and advancement to be made in the machining processes that are used to produce these part. Conventional machining processes are being pushed to their limits of performance and productivity. Many non-traditional processes, such as electrical-discharge machining, electro-chemical machining, and ultrasonic machiningare being used to meet industries demands. Non-traditional processes do not rely on contact between the tool and the workpiece to remove material in the form of chips. In many cases, these processes use a tool that is softer than the workpiece, (Loveless,1993).

Besides that, surface topography also is of great importance in specifying the function of a surface. A significant proportion of component failure starts at the surface due to either an isolated manufacturing discontinuity or gradual deterioration of the surface quality. Typically are the laps and folds which cause fatigue failures and of the latter is the grinding damage due to the use of a worn wheel resulting in stress corrosion and fatigue failure.

The most important parameter describing surface integrity is surface roughness. In the manufacturing industry, surface must be within certain limits of roughness. Therefore, measuring surface roughness is vital to quality control of machining work piece.

Grinding may be classified in to groups as rough or non precision grinding and precision grinding. Snagging and off hand grinding are the common forms of the rough grinding where the metal is removed without regard to accuracy. In precision grinding, according to type of surface to be ground, it is classified in to external or internal grinding, surface and cylindrical grinding.

According to Dhinakarraj and Mangaiyarkarasi (2003), the process planner has a prior knowledge about the product quality likely to be produced on a component during grinding, optimum process sequence design and process parameter selection is feasible. A need therefore exists to develop intelligent predictive product quality performance and the process conditions. The qualities of machined parts play a crucial role in the functional capacity of the part and, therefore, a great deal of attention should be paid to keep consistent tolerances.

The achievement of desirable value is a very critical process as the parts have already passed through many machining stages. In order to maintain quality, the variables the affect the grinding process must be defined experimentally and monitored in process. The basic target of the grinding process is to achieve the required shape, size and surface topography of the finished product in the most economical way. In modern manufacturing and assemblies, high dimensional accuracy and fine surface finish play an important role. One of the best low cost methods of producing such parts is by a cylindrical grinding.

In cylindrical grinding the external cylindrical surfaces and shoulders of the work piece are grounds. The work piece is held between the centres or in the chuck of the machine. The improvement in surface finish on the work pieces leads to higher corrosion resistance, fatigue strength and reduced power loss due to friction.

1.3 PROBLEM STATEMENT

The most important parameter describing surface integrity is surface roughness. In the manufacturing industry today, surface must be within certain limits of roughness. Therefore, measuring surface roughness is vital to quality control of machining work piece. Surface roughness also is great concern in manufacturing industrial environment. Parts such as automobile, aerospace, and medical component need high precision in surface finish. So there are problems in attempt to get high quality surface finish of product.

Besides that, optimization of grinding parameter is usually a difficult work where the following aspects are requiring such as knowledge of machining and specification of machining tools capabilities. The optimization parameters of machining are important especially in produce maximize production rate, reduce cost and production rate.

1.4 OBJECTIVES OF THE PROJECT

The objectives of this study is to;

(1) Perform experiment using Cylindrical Grinding Machine.

(2) Investigate the effect of parameter that influences the surface roughness on carbon steel.

(3) Determine optimum cylindrical grinding process parameters.

1.5 SCOPES OF THE PROJECT

Scopes of this project is:

(1) Performed cylindrical grinding operation on carbon steel rod.

(2) Grinding parameters considered are work speed, diameter of workpiece and depth of cut.

(3) Perthometer S2 was used to measure the surface roughness of the workpiece.

(4) STATISTICA software used to analyze the collected result.

(5) Study is used the application of Full Factorial method to optimize the cutting parameter.

(6) Used the Analysis of Variance (ANOVA) to get relationship between dependant and independent variables.

(7) All material and machines used available at mechanical lab.

1.6 ORGANIZATION OF THESIS

This thesis consists of five chapters. Chapter 1 present overview of this project was told. Problems occurred in industrial environment such as in cost, production rate and time were stated in this chapter. Besides that, the objectives and scopes regarding to this project were told.

Chapter 2 present the finding and previous study regarding to this project title were told. Most of the finding is based on published journal from previous experimentation and study. From the finding, the general information about the project can be gathered before the experiment began.

Chapter 3 presents a process from beginning until the end of this project were conduct in order to achieve the objectives. There are some process for this project including the method and parameters, apparatus that used in this experiment, and experiment setup. This experiment was performed under three different parameters. The parameters are work speed, depth of cut, and diameter of workpiece. There are several machines used in order to finish this project like by Horizontal Band Saw machine, Lathe machine, Cylindrical Grinding machine and Perthometer S2. Besides that, this project also used software like STATISTICA software.

Chapter 4 presents the result and the analyses for the experiment from the beginning until the end of the experiment were presented. All the data and the analysis used to explain the effect on surface roughness. The data and the analysis also used to determine the parameter that influence the surface roughness in the machining process.

Lastly for chapter 5 presents the conclusion of the project based on the project objectives and the project scopes. The recommendation also was in this chapter as the recommendation provided the information to improve the experiment in the future. These recommendations also were help other researcher to enhance the data and the result for this experiment.

1.7 SUMMARY

This chapter discussed generally about overview of this project, problem statement, question which has been formulate from the problems, objectives of the project and scopes of the project in order to achieve the objectives as mentioned.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the finding and previous study regarding to this project title were told. Most of the finding is based on published journal from previous experimentation and study. From the finding, the general information about the project can be gathered before the experiment began.

2.2 SURFACE ROUGHNESS

Every machining operation leaves characteristic evidence on the machined surface .The quality of machined surface is characteristics by the accuracy of manufacture with respect to the dimensions specified by the designer. Surface roughness is a variable often used to describe the quality of ground surfaces and also to evaluate the competitiveness of the overall grinding system. Surface roughness is one of the most important features of a machining process because it affects the functions of the part. In a grinding process, it is very important to keep the surface roughness within specified requirements because this process is the final machining process which usually at the last stage of the machining, (Agarwal, 2010).

According to Marinescu (2006), the ability of manufacturing operation is base on many factors. The final surface depends on the rotational speed of the wheel, work speed, feed rate, types of workpiece being machined, depth of cut, diameter of workpiece, types of wheel, and others parameter that can effect to the surface finish of the workpiece. Type and amounts of lubricant use for grinding process also influence the surface roughness. Different types of machine have different variable parameters that can be change to get the best surface finish.

Kalpakjian et al (2006) explain about regardless of the method of the production, all surfaces have their own characteristics which collectively are referred to as surface structure .As a geometrical property is complex, certain guide lines have been established for texture in terms of well defined and measurable quantities. Figure 2.1 shown standard terminology and symbols to describe.

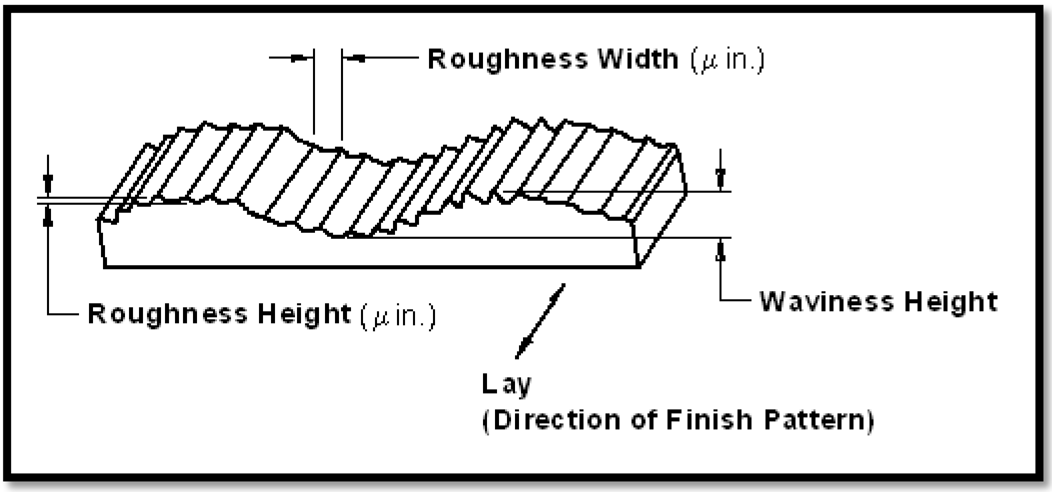

Figure 2.1: Standard Terminology

Source : Kalpakjian et al 2006

Surface roughness generally is described by two methods. The arithmetic mean value (Ra) is based on the schematic illustration of a rough surface, as shown in equation. it is defined as;

$$Ra = \frac{a + b + c + \cdots}{n}$$

Source : Kalpakjian et al 2006

Where all ordinates,a,b,c and etc. are absolute values and n is the number of readings. The root mean square roughness (rq, formerly identified as RMS) is defined as shown in equation;

$$Rq=\frac{\sqrt{a^2}+b^2+c^2+d^2+\ldots}{n}$$

Source : Kalpakjian et al 2006

The datum line in figure 2.2 is located so that the sum of the areas above the line is equal to the sum of areas above line is equal to the sum of areas below the line. The maximum roughness height (Rt) also can be used as defined as the height from the deepest through to the highest peak. It indicates how much material has to be removed in order to obtain in a smooth surface, such as by polishing. The units generally used for surface roughness are µm (micron). In general a surface cannot be described by its Ra or Rq value alone, since these values are averages. Two surfaces may have the same roughness value but have actual topography which is very different. For example, a few deep through on an otherwise smooth surface will not affect the roughness values significantly. However the type of surface profile can be significant in terms of friction, wear and fatigue characteristics of a manufactured product. Consequently, it is important to analyze a surface in great detail, particularly for parts to be used in critical applications,(Kalpakjian, et al 2006).

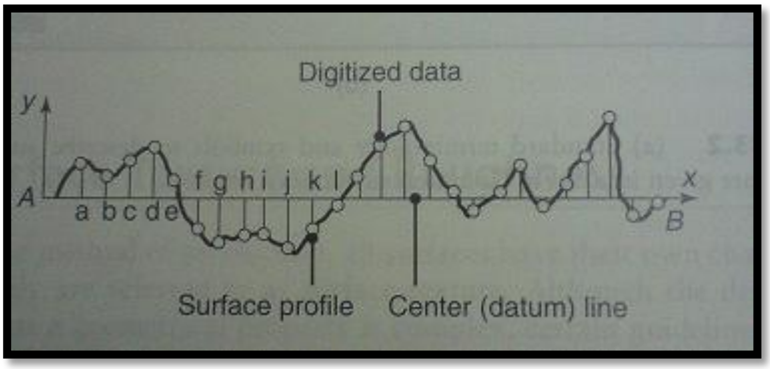

Figure 2.2: Datum Line

Source : Kalpakjian et al 2006

2.3 MACHINES

2.3.1 Horizontal Band Saw

Horizontal band saw (figure 2.3) is a power tool which uses a blade consisting of a continuous band of metal with teeth along one edge to cut various work pieces. The band rides on two wheels rotating in the same plane. The saw may be powered by electrical motor. Band sawing produces uniform cutting action as a result of an evenly distributed tooth load. Band saws are used for metalworking or for cutting a variety of other materials, and are particularly used to produce straight cuts. The radius of a curve that can be cut on a particular saw is determined by the width of the band and its lateral flexibility (Authorite, 2010).

Figure 2.3: Horizontal Band Saw

Source: Authorite, 2010

2.3.2 Lathe Machine

Turning center or lathe (Figure 2.4) is very common process found in manufacturing industry which is spins the workpiece to perform various operations such as cutting, sanding, knurling, drilling, or deformation with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation. There are a number of other lathe machine types such as bench lathes, special-purpose lathes, tracer lathes, automatic lathes, automatic lathes and computer-controlled lathes. The dimensional accuracy and surface finish obtained in turning and related operations depend on several factors such as the characteristics and condition of the machine tool, stiffness, vibration and chatter, process parameters, tool geometry and wear, the use of cutting fluids, the machine ability of the workpiece material, and operator skill. Vibration during cutting can cause poor surface finish, poor dimensional accuracy, excessive tool wear and premature failure (Kalpakjian et al 2006). The precision of CNC or NC machine is defined by is resolution. The resolution of this machine is typically 0.001 mm. This precision is depend on the machine part which is the spindle, hydraulic and the workpiece clamping.

Figure 2.4 : Lathe Machine

Wang,Y. et al (2001), explained about an effective reliability method is needed to allocate system level reliability requirements into subsystem and component levels. A comprehensive method is proposed in this paper for allocating the required system reliability level into each subsystem. Actions should be taken to improve the reliabilities of this subsystem such as turret, clamping accessory and so on.

Tlusty (2000) state that facing is part of the turning process. It involves moving the cutting tool across the face (or end) of the work piece and is performed by the operation of the cross-slide, if one is fitted, as distinct from the longitudinal feed (turning). It is frequently the first operation performed in the production of the work piece, and often the last- hence the phrase "ending up". The bits of waste metal from turning operations are known as chips (North America), or swarf in Britain. In some locales they may be known as turnings.

2.3.3 Cylindrical Grinding Machine

In grinding operation, the quality of surface finish is an important requirement of many work pieces. Taraman (1974) state that numerous authors have published studies aimed at evaluating the effects of the cutting parameter variations on surface finish. Cylindrical grinding is a process used to finish grind the outside or inside diameter of a cylindrical part by use cylindrical grinding machine (Figure 2.5). According to Ratcliffe (2010), cylindrical grinding produces a high quality finish and excellent accuracy and is usually a standard requirement for high accuracy parts.

The surface finish of an efficiently carried out grinding process is usually much finer than that of a lathe operation. A smooth glassy finish lacking any obvious machine ridges is typically achieved. That, coupled with the extremely high level of fine tolerance possible makes cylindrical grinding very suitable for operations that does require a trained and experienced operator to routinely produce work to this level of precision.

Figure 2.5: Cylindrical Grinding Machine

Source: Ratcliffe 2010

Grinding cylindrical work pieces differs from the operation of a lathe in one important manner in that the cutting tool, the grinding wheel, rotates as well as the work piece. Both items usually rotate at different speeds, which requires a precise calculation to determine the optimal cutting speed. Cylindrical grinding can be carried out by traversing the length of the surface, or plunge cutting can be used for narrower features. For centre grinding the work piece is either held between two centres and driven by a drive dog, or one end is driven by a chuck and the other end is located by the centre. For internal grinding the work piece is commonly held in a chuck only (Manufacturelink, 2010).

One of the advantages of cylindrical grinding is that work pieces can be hardened or have hard coating applied before final finishing by grinding. As the hardening processes often distort the metal, centre grinding makes it possible to ‘true up’ and accurately finish hardened shafts. Another advantage of cylindrical grinding is that the fine finish reduces surface stress raisers and therefore reduces fatigue cracking.

2.3.4 Perthometer S2

Typically, instrument called Perthometer S2 are used to measure and record surface roughness. In Perthometer S2 (Figure 2.6), the stylus is loaded on the surface to be measured and then moved across the surface at a constant velocity to obtain surface height variation (Boubekri et al, 1992). Perthometer S2 is characterized by a multitude of functions. After carrying out a measurement, periodic and non-periodic profiles can be identified and the cutoff set according to standards automatically, such that unintentional non-standard measurements are excluded explained in Mahr GmbH, (2010).

The distance that the stylus travels is called the cutoff, which generally ranges from 1.75 mm to 17.5mm. The rule of thumb is that the cutoff must be large enough to include 1 to 5 roughness irregularities, as well as all surface waviness. In order to highlight the roughness, the Perthometer S2 traces are recorded on an exaggerated vertical scale that is a few order of magnitude larger then horizontal scale. The magnitude of the scale is called gain on the recording instrument. Thus the recorded profile is distorted significantly, and the surface appears to be much rougher than it actual is. The recording instrument compensates for any surface waviness.

Figure 2.6: Perthometer S2

Source: Boubekri et al 1992

Because of the finite radius of the diamond stylus tip , the path of the stylus is different than actual surface and the measured roughness is lower. The smaller stylus diameter and the smoother surface, the closer is the path of the stylus to the actual surface profile (Kalpakjian, et al 2006).

In mobile use, the measuring record can be output on be built-in thermal printer automatically or simply by pressing a key. Stationary operation offers the possibility of connecting the Perthometer S2 directly to a PC via the serial Mahr GmbH, (2010).

2.4 GRINDING WHEEL

Grinding wheel is made of natural or synthetic abrasive minerals bonded together in a matrix to form a wheel. While such tools may be familiar to those with home workshops, the general public may not be aware of them because most have been developed and used by the manufacturing industry. In this sector, grinding wheels have been important for more than 150 years,(Salmon and Stuart ,1992).

The wheels is design as a precise and tightly controlled process, due not only to the safety risks of a spinning disc but also the composition and uniformity required to prevent that disc from exploding due to the high stresses produced on rotation, (Youssef, 2008).

Aluminum oxide, silicon carbide, diamond, and cubic boron nitride (CBN) are four commonly used abrasive materials for the surface of the grinding wheels. Of these materials, aluminum oxide is the most common. Because of cost, diamond and CBN grinding wheels are generally made with a core of less expensive material surrounded by a layer of diamond or CBN. Diamond and CBN wheels are very hard and are capable of economically grinding materials, such as ceramics and carbides, which cannot be ground by aluminum oxide or silicon carbide wheels.

2.4.1 Aluminium Oxide

As an angular, durable blasting abrasive, aluminum oxide or aluminium oxide as figure 2.7 can be recycled many times. It is the most widely used abrasive grain in sand blast finishing and surface preparation because of its cost, longevity and hardness. Harder than other commonly used blasting materials, aluminum oxide grit powder penetrates and cuts even the hardest metals and sintered carbide, (Loveless ,1993)

Approximately 50% lighter than metallic media, aluminum oxide abrasive grain has twice as many particles per pound. The fast-cutting action minimizes damage to thin materials by eliminating surface stresses caused by heavier, slower cutting media.

Figure 2.7 : Aluminum Oxide wheel

Aluminum oxide grit powder has a wide variety of applications, from cleaning engine heads, valves, pistons and turbine blades in the aircraft industry to lettering in monument and marker inscriptions. It is also commonly used for matte finishing, as well as cleaning and preparing parts for metalizing, plating and welding.

Aluminum oxide abrasive grain is the best choice for an abrasive sand blasting and polishing grain as well as for preparing a surface for painting.

2.4.2 Silicon Carbide

Silicon carbide (figure 2.8) is the hardest blasting media available. High-quality silicon carbide media is manufactured to a blocky grain shape that splinters. The resulting silicon carbide abrasives have sharp edges for blasting. Silicon carbide has a very fast cutting speed and can be recycled and reused many more times than sand. The hardness of silicon carbide allows for much shorter blast times relative to softer blast media.

According to Loveless (1993), Silicon carbide grit is the ideal media for use on glass and stone in both suction or siphon and direct pressure blast systems. The ability to be recycled multiple times results in a cost-effective silicon carbide grit blast media with optimal etching results. Since silicon carbide grit is harder than aluminum oxide, it can be used efficiently for glass engraving and stone etching. Silicon carbide grit blast media has no free silica, does not generate static electricity and is manufactured to contain minimal magnetic content.

Figure 2.8 : Silicon Carbide wheel

Silicon carbide grit is the ideal media for use on glass and stone in both suction or siphon and direct pressure blast systems. The ability to be recycled multiple times results in a cost-effective silicon carbide grit blast media with optimal etching results. Since silicon carbide grit is harder than aluminum oxide, it can be used efficiently for glass engraving and stone etching. Silicon carbide grit blast media has no free silica, does not generate static electricity and is manufactured to contain minimal magnetic content.

2.5 GRINDING PARAMETERS

Grinding is a complex manufacturing process with a large number of interacting variables, which depend on the type of grinding employed. The geometry produced in the surface grinding is influenced by many variables given as follows, Shaw (1996);

2.5.1 Wheel Characteristic

Grinding wheel is made up of abrasive grains held together by a bond. By varying the properties of the abrasive, the type of bond, and the structure of the wheel, it is possible to produce innumerable grinding characteristics.

(1) Bond

The function of the bond is to hold the abrasive grains in a definite spacing to form a product of defined size and shape.The most commonly used bonds are:

Vitrified-The rigidity of this bond is excellent for precision grinding and fast stock removal.

Resin - Organic bond makes the wheel tougher, suited for heavy-duty operations, high operating speeds, rough grinding, and cut-off applications.

(2) Wheel Structure

Wheel structure is closely related to porosity which determines the percentage of bulk volume of pores in unit volume of grinding wheel. It is marked with numbers 3-18, ranging from thick to very porous wheels. According to the shape and layout of pores, there are wheels of open and close porosity. Wheels of low porosity contain higher percentage of abrasive grains in a single unit volume than porous wheels.

2.5.2 Depth of cut

The depth of cut may be defined as the depth of the chip taken by the cutting tool and is one-half the total amount removed from the workpiece in one cut.

2.5.3 Wheel Speed

Wheel speed is defined as the work moves or rotating with respect to the tool, usually measured in revolution per minute.

2.5.4 Feed Rete

Feed rate is defined as the speed of the cutting tool’s movement relative to the workpiece as the tool makes cut.It is measured in milimeter per minute(mm/min).

2.5.5 Spindle/Work Speed

The spindle/work speed is the rotational frequency of the spindle of the machine, measured in revolutions per minute (RPM). The preferred speed is determined based on the material being cut.

Peters (1984) and Brinksmeier, et al (1993) were explained many of investigations have been carried out to understand relationship between grinding conditions and their influence on machining. Based on this project, work speed, diameter workpiece, and depth of cut will be choosing as variables to proceed this project. Other variables are constant.

2.6 MATERIAL

Carbon steel (Figure 2.9) is a type of steel alloy, that contains a high amount of carbon (0.40%of C) as a major constituent. Pilgrim (2010) said an alloy is a mixture of metals and non-metals, designed to have specific properties. Alloys make it possible to compensate for the shortcomings of a pure metal by adding other elements.

Figure 2.9: *AISI 1042*

Source: Pilgrim 2010

AISI 1042 is a Standard grade *Carbon Steel*. It is composed of (in weight percentage) 0.40-0.47% Carbon (C), 0.60-0.90% Manganese (Mn), 0.04%(max) Phosphorus (P), 0.05%(max) Sulfur (S), and the base metal Iron (Fe). Other designations of AISI 1042 carbon steel include UNS G10420 and AISI 1042.

They prevent dislocations from occurring inside the iron crystals and prevent the lattice layers from sliding past each other. This is what makes steel harder than iron. Varying the amounts of these hardening agents, creates different grades of steel. The ductility, hardness and mild steel tensile strength is a function of the amount of carbon and other hardening agents, present in the alloy. The amount of carbon is a deciding factor, which decides hardness of the steel alloy.

A steel alloy with a high carbon content is carbon steel, which is in fact much harder and stronger than iron. Though, increased carbon content increases the hardness of the steel alloy, it causes a decrease in its ductility (Pilgrim, 2010; eFunda, 2010). Table 2.1, 2.2, and 2.3 showed the properties of AISI 1042;

Table 2.1: Mechanical Properties for AISI 1042

Properties		Conditions	
		T (°C)	**Treatment**
Density (×1000 kg/m^3)	7.844	25	
Poisson's Ratio	0.27-0.30	25	
Elastic Modulus (GPa)	190-210	25	
Tensile Strength (Mpa)	394.7	25	annealed at 870°C
Yield Strength (Mpa)	294.8		
Elongation (%)	36.5		
Reduction in Area (%)	66.0		
Hardness (HB)	111	25	annealed at 870°C
Impact Strength (J) (*Izod*)	123.4	25	annealed at 870°C

Source: Pilgrim 2010

Table 2.2: Thermal Properties for AISI 1042

Properties		Conditions	
		T (°C)	**Treatment**
Thermal Conductivity (W/m-K)	51.9	0	
Specific Heat (J/kg-K)	486	50-100	

Source: Pilgrim 2010

Table 2.3: Electric Properties for AISI 1042

Properties		Conditions	
		T (°C)	**Treatment**
Electric Resistivity (10^{-9}W-m)	171	20	-

Source: Pilgrim 2010

2.7 STATISTICA ANALYSIS

2.7.1 Statistica Software

STATISTICA' originally derives from a set of software packages and add-ons which were initially developed during the Mid 80's by StatSoft. More specifically in 1985 The Statistical Supplement for Lotus 1-2-3 was released and was the first statistics add on developed for the Lotus spreadsheet. This was later released as a standalone called STATS+. The STATISTICA line of software consists of a fully integrated line of analytic, graphics, and data management solutions and libraries, developed and refined over the past 25 years, and validated over decades by thousands of individual users and in enterprise installations worldwide, often for critical data analyses or in mission/business critical applications.

STATISTICA also is a carefully planned, brilliantly designed, and meticulously executed line of software solutions that follows industry-standard software rules and interfaces, language standards, accessibility standards, UI recommendations. STATISTICA solutions were developed to get things done, to provide the fastest return on investment, best value, and uniquely useful and effective analytic, data management, graphics, and presentation tools to create predictable value quickly for you and your organization and applications, (StatSoft,2010)

2.7.2 Design of Experiment

To plan the experiment, collecting and analyzing the data in systematically and scientific way, the finer approach is by using the designed experiment because it can be done with limited use of available resource before the experiment (Dubey,2006). By using the design of experiment, instead of making the data in systematically order, it also helped in reducing the error during the experiment. The relationship between the input and the output value can be expressed by using a mathematical model in terms of the mathematical equations. From the model, the calculated value would be use to check the accuracy of the model. Furthermore, it also helped to further understand the complex process in grinding process.

In experiment involving several factors where it need to study the joint effect of the factor on a response, factorial designs are frequently used. Though, there are several special cases involving the general factorial designs which important. This is because it can be use to form the basis of other designs that can be considerable practical value and they had been widely employed in research work.(Montgomery, 2003).

3^k factorial design is a complete replicate of design that require $3 \times 3 \times \cdot\cdot \times 3 = 3^k$ observations. It is a design that is useful at the early stages of experimental work that required many factors to be investigated and examine. This model can be use to provide smaller number of runs when the experiment needed to be in many runs. And, since there are only two levels for each factor, the response should be assume approximately linear over the range of the factor levels chosen. (Montgomery,2003).

2.7.3 Contour Plot

This sequential plot can be considered to be a 2D (figure 2.10) projection of the 3D Ribbons plot (figure 2.11). Each data point in this plot is represented as a rectangular region, with different colours and patterns corresponding to the values (or range of values of the data points (the ranges are described in the legend). Values within each series are presented along the X-axis, with each series plotted along the Y-axis.

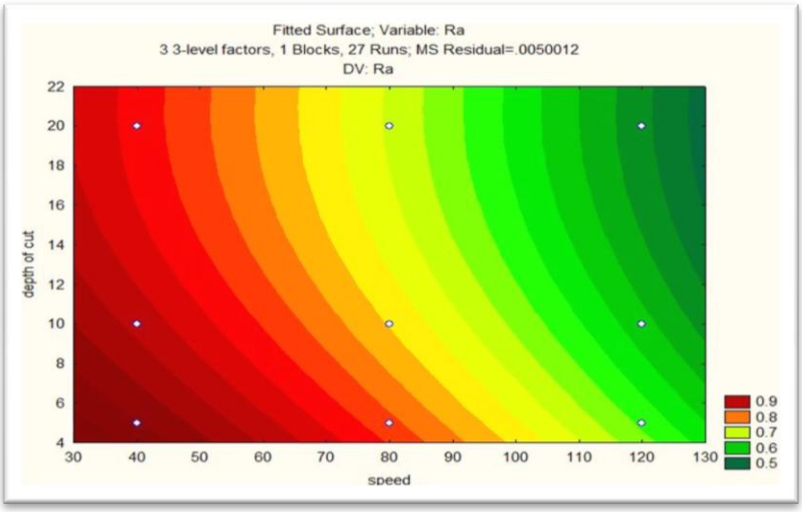

Figure2.10: 2D Contour plot graph

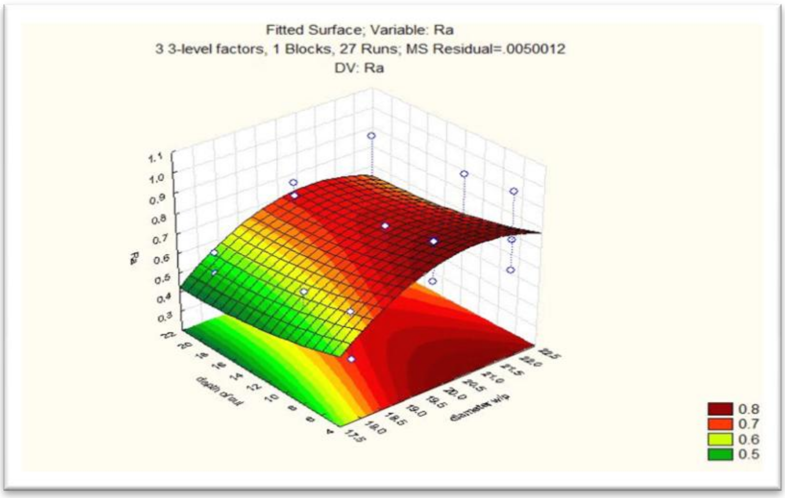

Figure 2.11: 3D Contour plot graph

2.7.4 Normal Probability Plot

Normal Probability Plots (Computation Note). The following formulas are used to convert the ranks into expected normal probability values, that is, the respective normal z values.

2.7.5 Analysis of Variance (ANOVA)

ANOVA is a basic statistical technique for analyzing experimental data. It divides the total variation of a data set into meaningful component parts associated with specific sources of variation in order to test the hypothesis on the parameters of the experiment or estimate variance components. ANOVA also used to test whether the mean of many samples different but it does so using variation instead of mean. It compares amount of variation within the samples to the amount of variation between the means of samples. If the variation is significantly larger than the within variations, it can conclude that the mean of response has changed.

According to Muthukrishnan ,(2008), ANOVA extends the two sample t-test for testing the quality of two population means to a more general null hypothesis of comparing the equality of more than two means versus them not all being equal. Null hypothesis represent the current view or explanation of an aspect of the world that want to challenge.

There are some types of ANOVA can used to analysis the data such as One-Way ANOVA,Two-Way ANOVA, Analysis of Mean and others. One -way ANOVA compares three or more levels of one factor. But some experiments involve two factors each multiple levels in which case it is appropriate to use Two-Way ANOVA.

2.8 MATHEMATICAL MODEL: REGRESSION MODEL

If there are more than one regressor variable, the regression analysis can be applied to analyze the situations. A multiple regression model need to be use when there are more than one regressor variable for a regression model. As example, the surface roughness generated by the grinding process depends on wheel speed, diameter of workpiece and deptof cut. The multiple regression model that can be use to describe the relationship between those parameter is :

$$Y=\beta_0 + \beta_1 x_1+\beta_2 x_2+ \beta_3 x_3+\epsilon \tag{2.1}$$

Source: Montgomery 2003

Where Y represents the surface roughness, x_1 represents the wheel speed, x_2 represents diameter of work piece, x_3 represents the depth of cut and ϵ is a random error term. The equation called as the multiple linear regression models with three regressors. The Equation (2.1) is a linear function for the unknown parameters which is the β_0, β_1, β_2 and β_3 and that is why the term linear used for the regression model. The expected value of the error term, ϵ can be assumed zero. Partial regression sometimes can be use to represents β_1 and β_2 since the expected change for Y per unit change of x_1 when the x_2 are being held constant for measuring the β_1, and the expectedchange for Y per unit change of x_2 when the x_1 are being held constant for measuring the β_2. (Montgomery, 2003).

For approximating a functions, the regression model that regularly be used is the multiple linear regression models. There is unknown relationship of true functional between Y and x_1, x_2 and x_3, but the linear regression model is an adequate approximation over certain range of the independent variables that will be investigated for a functions. To find the interaction between the effect for a certain analysis, the multiple linear regression model also can be use to analyzed the effect. The interaction can be made by cross the product in the model, such as

$$Y= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{23} x_2 x_3 + \beta_{13} x_1 x_3 + \epsilon \tag{2.2}$$

Source: Montgomery 2003

Generally, not considering the shape of a surface plot that had been generated by the model, a linear regression model is a model that is linear in the parameters. Linear in parameters means that the β's is linear. (Montgomery, 2003).

2.9 PREVIOUS METHODS

2.9.1 Prediction of Surface Roughness and Roundness Error in Cylindrical Grinding by Artificial Neural Network (ANN)

This journal present “Prediction of Surface Roughness and Roundness Error in Cylindrical Grinding by Artificial Neural Network (ANN)” written by C.K. Dhinakarraj and P.Mangaiyarkarasi from Department of Mechanical Engineering, Adhiparasakthi Engineering College, Melmaruvathur. This journal was about prediction the surface roughness of grind parts in the cylindrical grinding process is developed in this project to assure product quality by predicting the surface finish parameters in real time.

There are three parameters involved in this project such as spindle speed, feed rate and depth of cut as three input neurons an artificial neural networks (ANN) model based on back propagation is developed to predict the output neuron-surface roughness (Ra) and Roundness Error (R) values. The experiment and its results proposed to ANN surface recognition model for a high accuracy rate by predicting surface roughness and roundness error under a variety of combinations of cutting conditions. This system also economical, efficient and can able to be implement to achive the goal of in-process surface recognition and giving feed back to the operation for the necessary corrective action.

From this paper, it is concluded that the surface roughness increases with increase in feed rate, depth of cut and speed by keeping other cutting parameter as constant. Also it is concluded that the roundness error is increases with increase in feed rate, depth of cut and speed by keeping other cutting parameter are constant. Furthermore, the effects of cutting parameters can be changes depending on selection of cutting parameters, type of grinding wheel and grinding condition (wet or dry).

2.9.2 Multi-Parameter Optimization of the Cylindrical Grinding Process

The title of this journal is “Multi-Parameter Optimization of the Cylindrical Grinding Process”that written by G.F.Li, L.S.Wang And L .B.Yang. They are from

College of Mechanical Science and Engineering, Jilin University, China. In this paper , they were proceeds beyond the limits on conventional no-burn thoughtand presenting an optimum strategy permitting burn to appear in the rough grinding stage. This paper also compared previous method from other researcher.

The objective functions and constrain functions for the multi-parameter optimum grinding process had been built in this paper. The non-linear optimum grinding control parameters had been obtained through computer simulation and the actual grinding process had been controlled by these parameters.

The result from this paper were present an optimum system for grinding process to minimize production time and proved the exactitude of the optimum models and feasibility of the optimum strategy.

2.9.3 Grinding Surface Characterization by CEST

The title of this journal is “Grinding Surface Characterization by CEST”, written by Y. Y. Huang and S. M. Wu. This paper received for publication on 23 January 1986. This paper is about a newly developed Computer Evaluation of Surface Topography (CEST) technique is used to characterize grinding surface. This CEST technique calculates the profile spectrial moments and finds variances of heights, slopes and curvatures of asperities for any anisotropic homogeneous surface in the form of pictorial conic sections. The objective of the present paper is to further apply CEST for grinding surface topography under different grinding conditions as compared with the conventional surface characterization techniques. Also, it intends to find a new relationship between the grinding conditions and the surface topography.

From this project, ten different soft steel ground surfaces were evaluated using CEST techniques to study the effects of five different operating variables on surface finish. Also, the cross-feed and depth of cut were shown to be the two strongest factors influencing the surface characteristics. Finally, suitable operating conditions for grinding soft steel are suggested to produce desired surface quality.

2.9.4 Analysis of Process Parameters in Surface Grinding with Graphite as Lubricant Based on the Taguchi method

This journal presents "Analysis of Process Parameters in Surface Grinding with Graphite as Lubricant Based on the Taguchi method" written by S. Shaji and V. Radhakrishnan .Both of authors from Manufacturing Engineering Section, Department of Mechanical Engineering, Indian Institute of Technology-Madras, Chennai, India and this paper was received on 24 September 2001 (accepted 12 November 2002).

This paper present investigation on cooling and lubrication by using grinding process. Cooling and lubrication are especially important to ensure workpiece quality in grinding, because of high friction and intense heat generation involved in the process. Conventionally, liquid coolants in flood form are employed in grinding.

Analysis of the process parameters such as speed, feed, depth of cut and mode of dressing were used in this project. Authors also have investigated the possibility of using graphite as lubricating medium to reduce the heat generated at the grinding zone in surface grinding with a newly developed experimental setup for the purpose. From this research, the authors used Taguchi's experimental design methods and ANOVA to analyse the experimental data.

As a result, the new experimental setup developed for the application of graphite as a means to reduce the heat generated in the grinding zone has been investigated for the analysis of various factors influencing the performance characteristics, following the Taguchi method of experimental design. It has been successfully applied for finding out the relative contributions of various factors such as speed, feed, infeed and mode of dressing on the surface roughness and the forces developed and for finding out the optimum factor level combinations. From this project generally agree with those of the conventional coolant grinding for the relative contributions of various factors affecting the quality characteristics.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter include of a process from beginning until the end of this project were conduct in order to achieve the objectives. There are some process for this project including the method and parameters, apparatus that used in this experiment, and experiment setup. This experiment was performed under three different parameters. The parameters are work speed, depth of cut, and diameter of workpiece.

There are several machines used in order to finish this project like by Horizontal Band Saw machine, Lathe machine, Cylindrical Grinding machine and Perthometer S2. Besides that, this project also used software like STATISTICA software.

3.2 GRINDING MACHINE

The grinding machine that used to run this experiment is Precision Surface Grinder. The type for this machine is OGM 250-EX (figure 2.3) from Okamoto Machine Tools, Japan. This type is equipped with two axles for left/right table feed and forward/back grindstone feed controlled by proprietarily developed NC equipment.

Besides that, this machine also has four processing mode types that are plunge cut, traverse cut, shift plunge cut, and manual traverse respectively. For dressing process, there are dress cycle inclusive of complete automatic cycling with free interrupted dress, edge dress, manual grinding mode, and teaching function.

3.3 GRINDING WHEEL

Grinding wheel that used for this experiment is Aluminum Oxide, (Al_2O_3). This type consist of more than 98% of Al_2O_3 . Therefore the grit size is consistent and cuts much faster than other sand blasting media, leaving a smoother surface.

Aluminum oxide is also an extremely sharp, long-lasting blasting abrasive that can be recycled many times after the initial media blasting. It is the most widely used abrasive in blast finishing and surface preparation because of its cost, longevity and hardness. Harder than other commonly used blasting materials, white aluminum oxide grains penetrate and cut even the hardest metals and sintered carbide. This type suitable for alloy and carbon steels with more than 0.5% contents of carbon.

3.4 EXPERIMENT SETUP

(1) Nine pieces of the mild steel rod were cut using Band Saw machine with length 150mm.

(2) Then, to get different diameter in sizes (18mm, 20mm and 22mm), the workpiece were machined using Lathe machine.

(3) After that, parameters according to the experiment table were adjusted and the grinding process using cylindrical grinding machine was ran.

(4) Then, by using Perthometer S2, surface roughness of the workpieces which already grind were checked.

(5) Lastly, recorded data from experiment were analyzed using STATISTICA software.

3.5 WORK PIECE PREPARATION

3.5.1 Cutting Operation

First step of this project is preparation on work piece. The material used of this project is AISI 1042 Carbon Steel. This steel was cut by Horizontal Band Saw machine. The dimension used of this workpiece is 25mm in diameter and length is 150mm (figure 3.1). During this machining process, choosing suitable parameter of this machine like cutting speed and feed rate must be set up depend on material used.

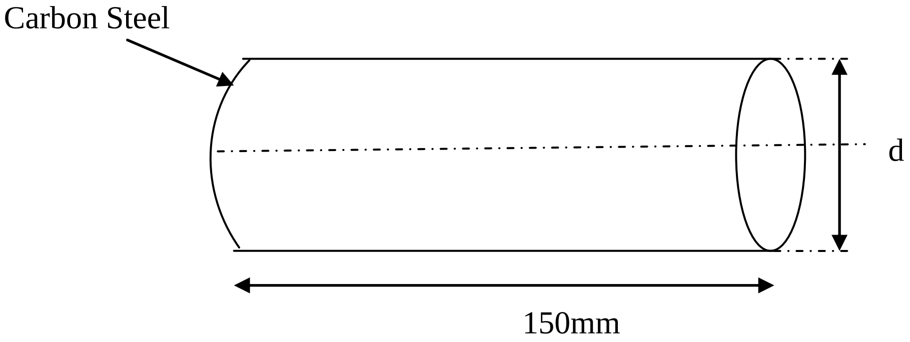

Figure 3.1: Workpiece Condition

3.5.2 Turning Operation

Lathe machine was used in this operation. The purpose of this process is to get the exact value of work piece's diameter which is 18 mm, 20 mm and 22mm. Besides that, this process also to get the rough surface for the workpiece before starting grinding operation.

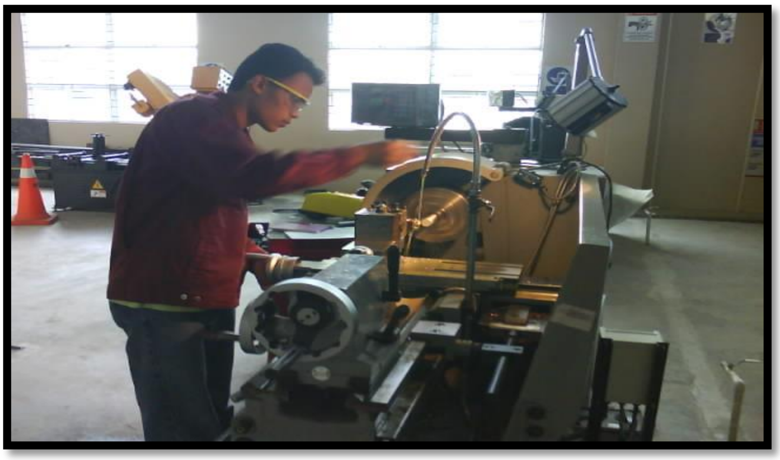

Figure 3.2: Turning Operation

After set up the lathe machine (figure 3.2) with the spindle speed and feed then start the machine and make a reference point by start cut a bit. Then the cutting operation starts by setting the X-axiz and Y-axis are both zero as the reference point on the outer surface tip end of the workpiece.

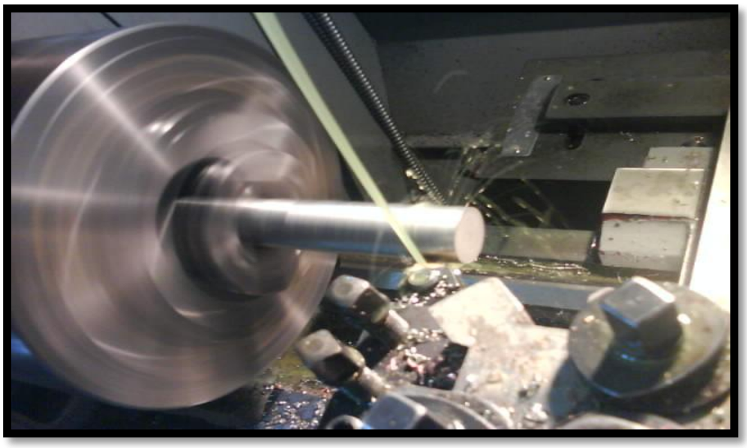

Figure 3.3: Cutting Process

As the machine has turned on (figure 3.3), 0.2 mm depth of cut is performed along the length of workpiece until get the exact diameter.

3.6 GRINDING OPERATION

Cylindrical grinding also called center-type grinding is used in the removing the cylindrical surfaces and shoulders of the workpiece. The workpiece is mounted and rotated by a workpiece holder, also known as a grinding dog or center driver. Both the tool and the workpiece are rotated by separate motors and at different speeds. The axes of rotation tool can be adjusted to produce a variety of shapes. Figure 3.4 below shows the setup of Cylindrical Grinding machine.

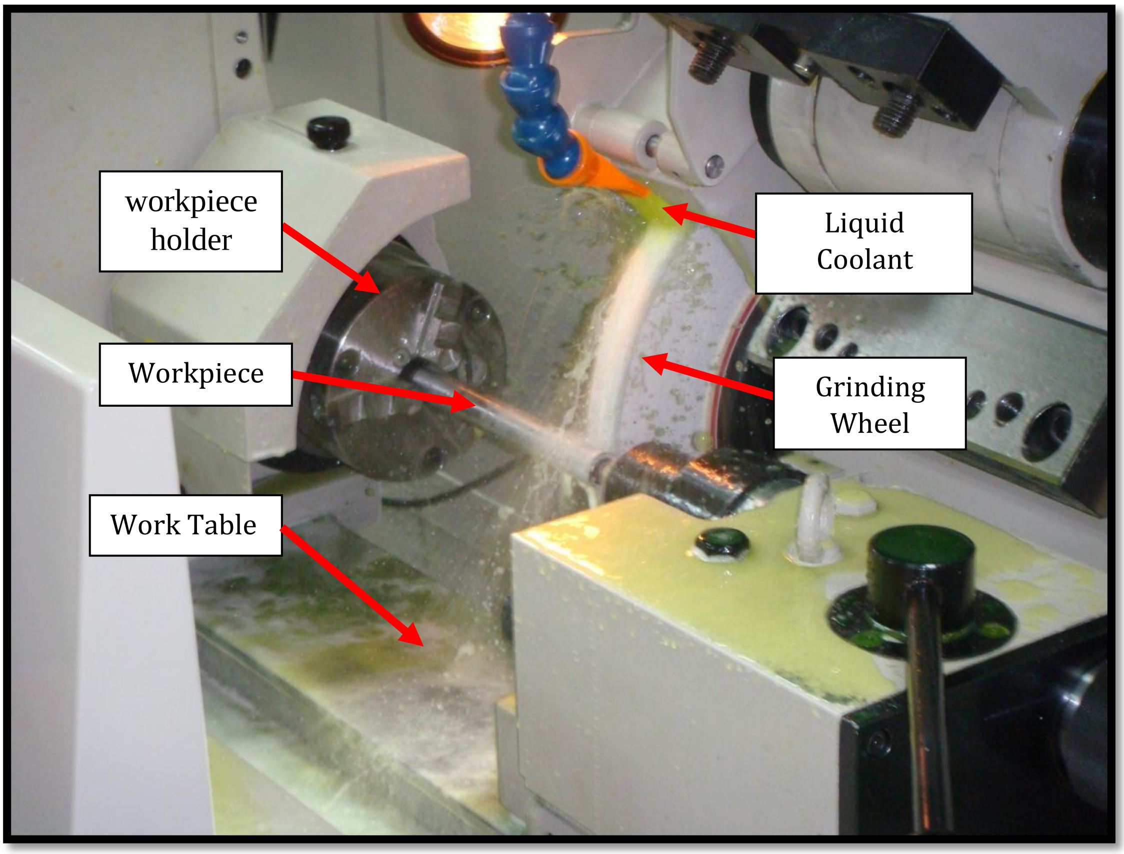

Figure 3.4: Cylindrical Grinding Operation

During this experiment, dependant variable for machine parameter were set which are work speed, diameter of workpiece and depth of cut. Each of these variables was applied for three levels. Other variables such as spindle speed, table speed, and feed rate are constant.

3.7 SURFACE ROUGHNESS MEASUREMENTS

Figure 3.5 is an experimental arrangement used to measure the surface roughness of turned part. A Perthometer S2 apparatus was used. The Perthometer S2 technique used in this study is common to most production shops. The Perthometer S2 measures surface roughness with a diamond stylus of a finite radius is traced across the surface profile to produce a voltage output which is proportional to the height of the surface profile.

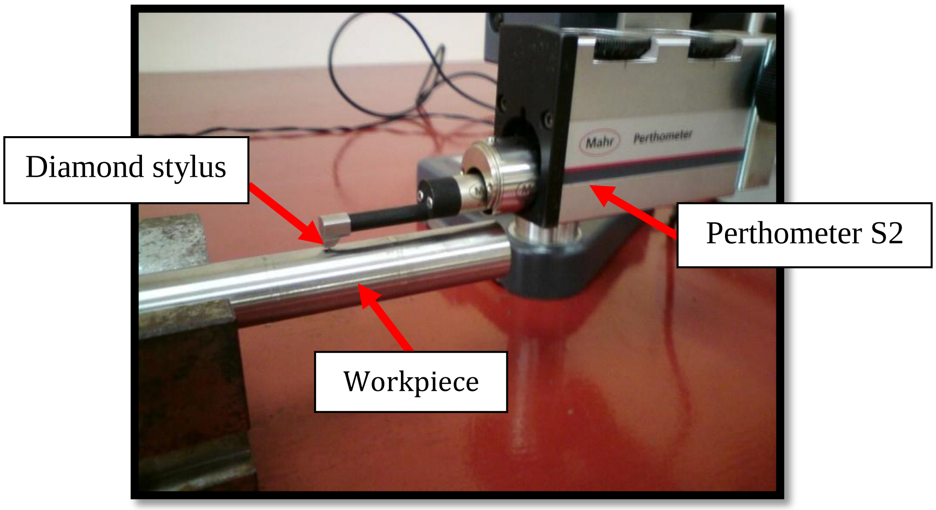

Figure 3.5: Surface Roughness Measurements

The stylus was traced along each cut area of the surface. The stylus was allowed to move back and the average value (Ra) as shown by the digital indicator was recorded as the value of surface roughness (μm). The Perthometer S2 accuracy was verified after each steel rod sample.

3.8 FACTORIAL DESIGN

Factorial design is a useful tool in order to characterize multivariable processes. It gives the possibility to separate the important factors from those, which are not, and identifying any possible interactions between them.

In this study, a 3^3 full factorial design was used to determine the effect of high quality of surface finish when applied optimize parameter of a cylindrical grinding operation. Before the application of the design a number of preliminary trials were conducted to determine the conditions at which the process resulted to pellets. The levels of the factors were also determined by this procedure. The factors and their levels are shown in Table 3.1.

The different formulations of the factorial design consisted of all possible combinations of all factors at all levels and were conducted in a fully randomized order. The matrix of the experiments and the results of the responses for every experiment are listed in Table 3.2.

3.9 CONDUCT AN EXPERIMENT

Assuming the grinding wheel is considered as a homogeneous structure and no dressing. As there are three variables (Work Speed, Diameter of workpiece and Depth of cut) and three levels, the numbers of experiments required for full factorial design. The experiments were carried out on a Cylindrical Grinding machine. An Aluminum Oxide grinding wheel and die coat cutting fluid were used for cylindrical grinding operations on mild steel work pieces.

Table 3.1: Levels of Independent Variables

Variables	**Unit**	**Range**	**Level**		
			1	**2**	**3**
Work Speed	rpm	40~120	Low	Medium	High
Diameter w/p	mm	18~22	Low	Medium	High
Depth of cut	μm	5~20	Low	Medium	High

Source: Dhinakarraj 2003

Table 3.2: Grinding Parameters and Experimental data

Order of run	**Work Speed** (rpm)	**Diameter w/p** (mm)	**Depth of Cut** (µm)	**Ra** (µm)
1	40	22	5	
2	40	22	10	
3	40	22	20	
4	40	20	5	
5	40	20	10	
6	40	20	20	
7	40	18	5	
8	40	18	10	
9	40	18	20	
10	80	22	5	
11	80	22	10	
12	80	22	20	
13	80	20	5	
14	80	20	10	
15	80	20	20	
16	80	18	5	
17	80	18	10	
18	80	18	20	
19	120	22	5	
20	120	22	10	
21	120	22	20	
22	120	20	5	
23	120	20	10	
24	120	20	20	
25	120	18	5	
26	120	18	10	
27	120	18	20	

Source: Dhinakarraj 2003

3.10 DATA ANALYSIS

This project used the Analysis of Variance (ANOVA) to analyze experiment data. ANOVA is the most widely used method of statistical analysis of quantitative data. It calculates the probability that differences among the observed means could simply be due to chance. Every scientist should know how to use it. It is closely related to Student's t-test, but whereas the t-test is only suitable for comparing two treatment means the ANOVA can be used both for comparing several means and in more complex situation. The ANOVA partitions the total variation into a number of parts such as Treatment, Block, Error and Total, depending on the design of the experiment.

STATISTICA Software was used to analyze ANOVA. This software can determine whether the parameter have the significant effect or not. This software also generated related table and graph needed in ANOVA.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter, the result and the analysis for the experiment from the beginning until the end of the experiment were presented. All the data and the analysis used to explain the effect on surface roughness. The data and the analysis also used to determine the parameter that influence the surface roughness in the machining process.

4.2 SURFACE ROUGHNESS EXPERIMENT RESULT

4.2.1 Surface Roughness Experiment Data

As mentioned in the methodology section, the experiment was made by making three various section on the mild steel. The work piece picture after the experiment was shows in Figure 4.1 :

Figure 4.1: Work piece picture after the machining process

From the figure, there are three section of the surface finish generated. The section showed the various parameter according to the design of the experiment. After that, the specimen was tested by using Perthometer S2 to measure and record surface roughness . Figure 4.2 and 4.3 showed the measurenment picture using the Perthometer S2.

Figure 4.2: Roughness measuring picture using the Perthometer S2

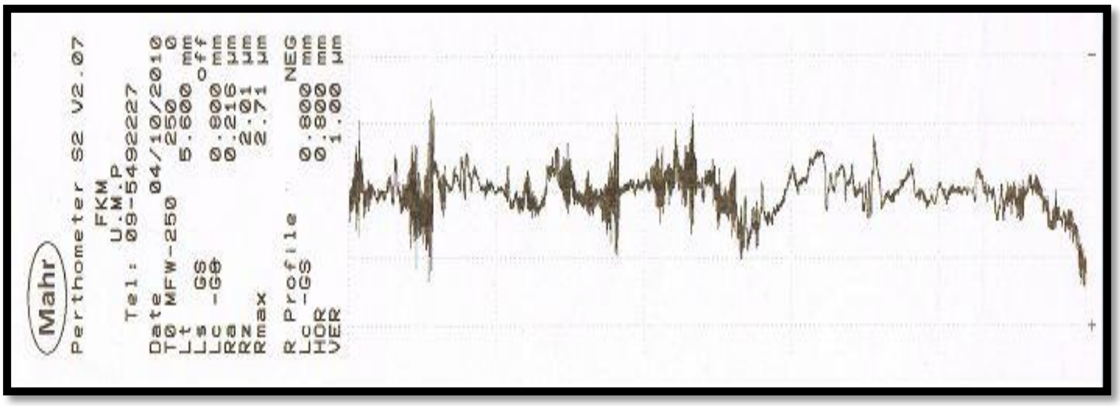

Figure 4.3: Example Result from Perthometer S2

After the surface roughness had been measured, the value then keyed in the table for STATISTICA analysis. The result from the experiment is shown as in Table 4.1 below.

Table 4.1: Table of result from surface roughness experiment

Order of run	**Work Speed** (rpm)	**Diameter w/p** (mm)	**Depth of Cut** (µm)	**Surface roughness** (µm)
1	40	22	5	0.989
2	40	22	10	0.963
3	40	22	20	0.928
4	40	20	5	0.897
5	40	20	10	0.847
6	40	20	20	0.827
7	40	18	5	0.704
8	40	18	10	0.673
9	40	18	20	0.614
10	80	22	5	0.756
11	80	22	10	0.646

Order of run	**Work Speed** (rpm)	**Diameter w/p** (mm)	**Depth of Cut** (µm)	**Surface roughness** (µm)
12	80	22	20	0.586
13	80	20	5	0.890
14	80	20	10	0.845
15	80	20	20	0.763
16	80	18	5	0.599
17	80	18	10	0.553
18	80	18	20	0.508
19	120	22	5	0.601
20	120	22	10	0.596
21	120	22	20	0.516
22	120	20	5	0.698
23	120	20	10	0.485
24	120	20	20	0.446
25	120	18	5	0.469
26	120	18	10	0.455
27	120	18	20	0.406

After the data had been put into the STATISICA analysis table, the data then was analyzed.

4.2.2 Work Speed , Diameter w/p and Depth of cut against Surface Roughness

Before continuing with other analysis, the data need to check first whether it is valid or not. The observed against predicted value need to generate first to check the validity of the data gathered. STATISTICA software used to generate observed against predicted value plot. Figure 4.4 showed the plotted graph.

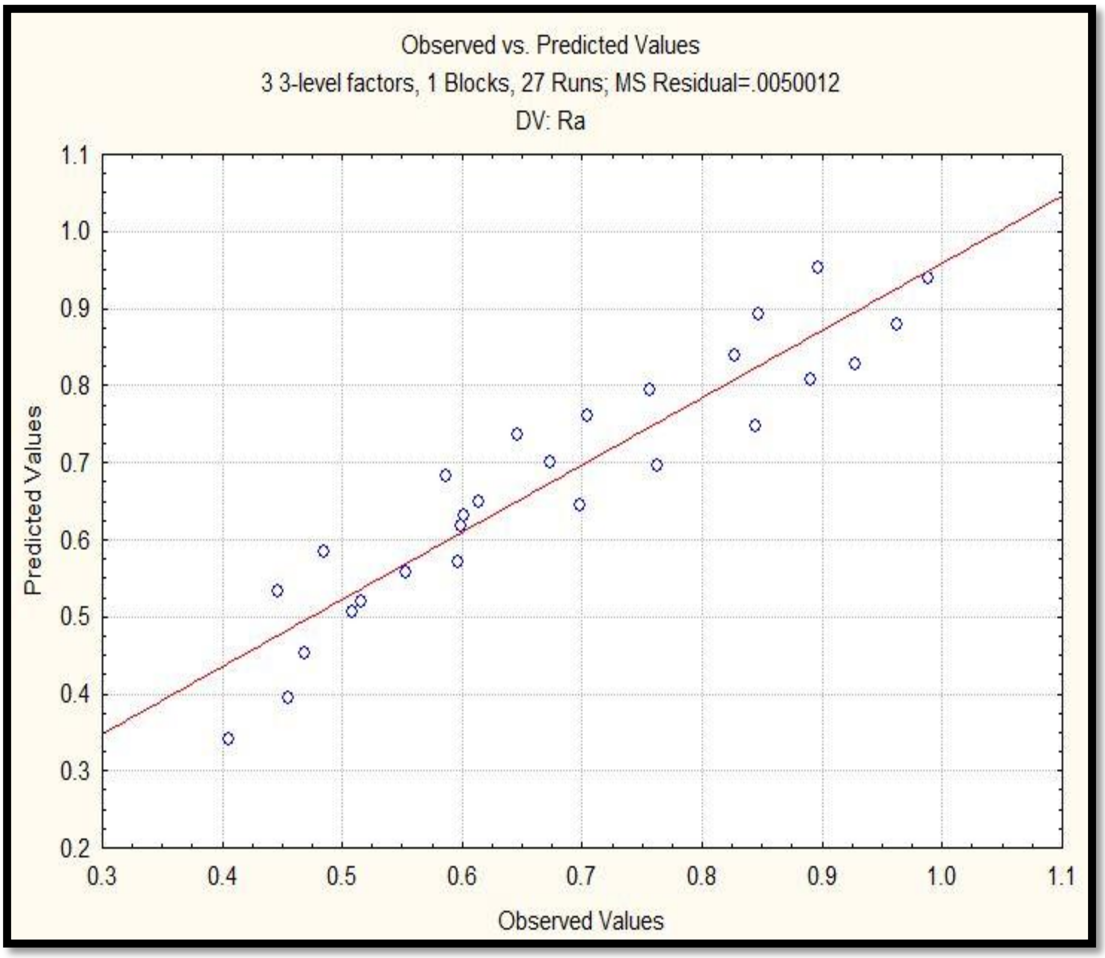

Figure 4.4: Graph Observed against predicted Value

Note that the predicted value were generated from the design of the experiment that had done before running the experiment. This figure then used to determine whether the data that had gathered can be use or not in this analysis. In this case, the plot of observed value was lies near to the predicted value line. This shows that the data can used for the analysis. After the data had examined, the data used for other analysis.

Table 4.2 showed the result of effect estimates for the surface roughness against all the independent variables that had generated using STATISTICA software.

Table 4.2 : Effect estimate table of surface roughness

Factor	Effect	Std Error	t(20)	p
Mean/intrc.	0.670068	0.013735	48.78396	0.000000
Work Speed	-0.29878	0.033337	-9.23218	0.000000
Diameter w/p	0.279667	0.033337	5.33267	0.000032
Depth of cut	-0.112111	0.033337	-3.36291	0.003095

Table 4.2 showed the highlighted columned which were all parameters gave the significant effect to the surface roughness. From STATISTICA, the surface plot for dependent variable was generated;

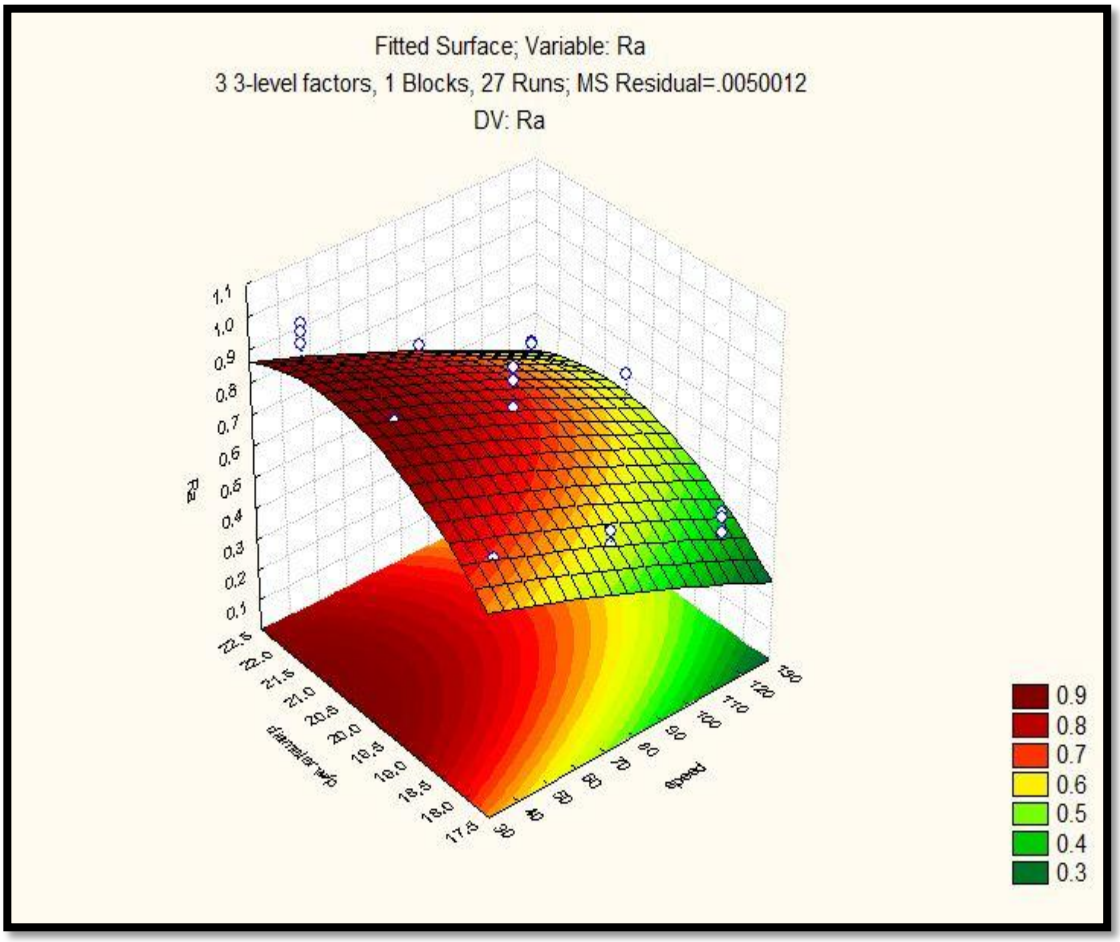

Figure 4.5: Surface plot of work speed and diameter w/p against generated Ra

Figure 4.5 showed surface plot were used in order to show the relation between three parameter simltaneously. Depth of cut value was constant that is 11.6667 μm, the highest value of work speed and the lower diameter of work piece got low value of surface roughness which is fine surface. Otherwise, the lower value of work speed and high value of diameter became the rougher surface.

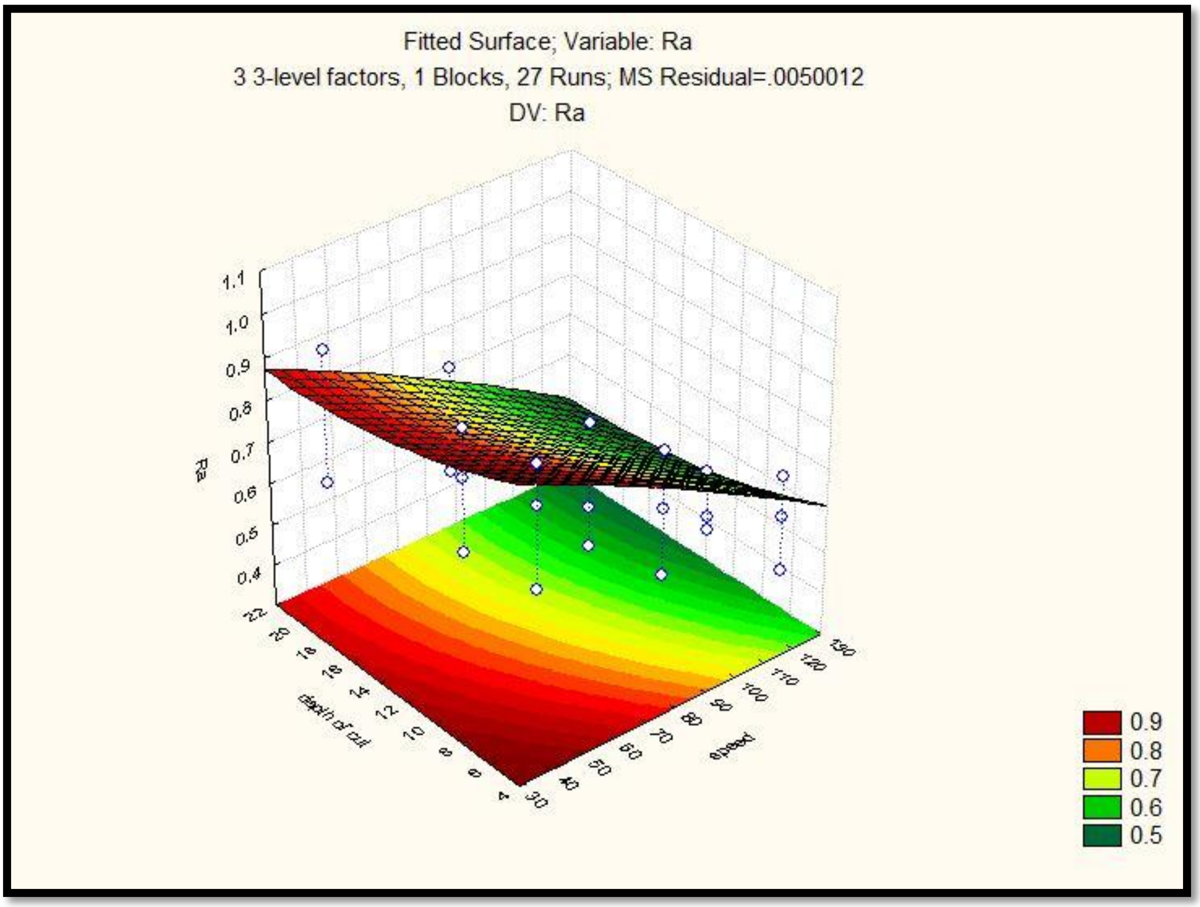

Figure 4.6: Surface plot of work speed and depth of cut against generated Ra

Figure 4.6 showed surface plot with constant diameter of work piece which is 20 mm. From the figure above were stated fine surface got when value of work speed and depth of cut were increased uniformly.

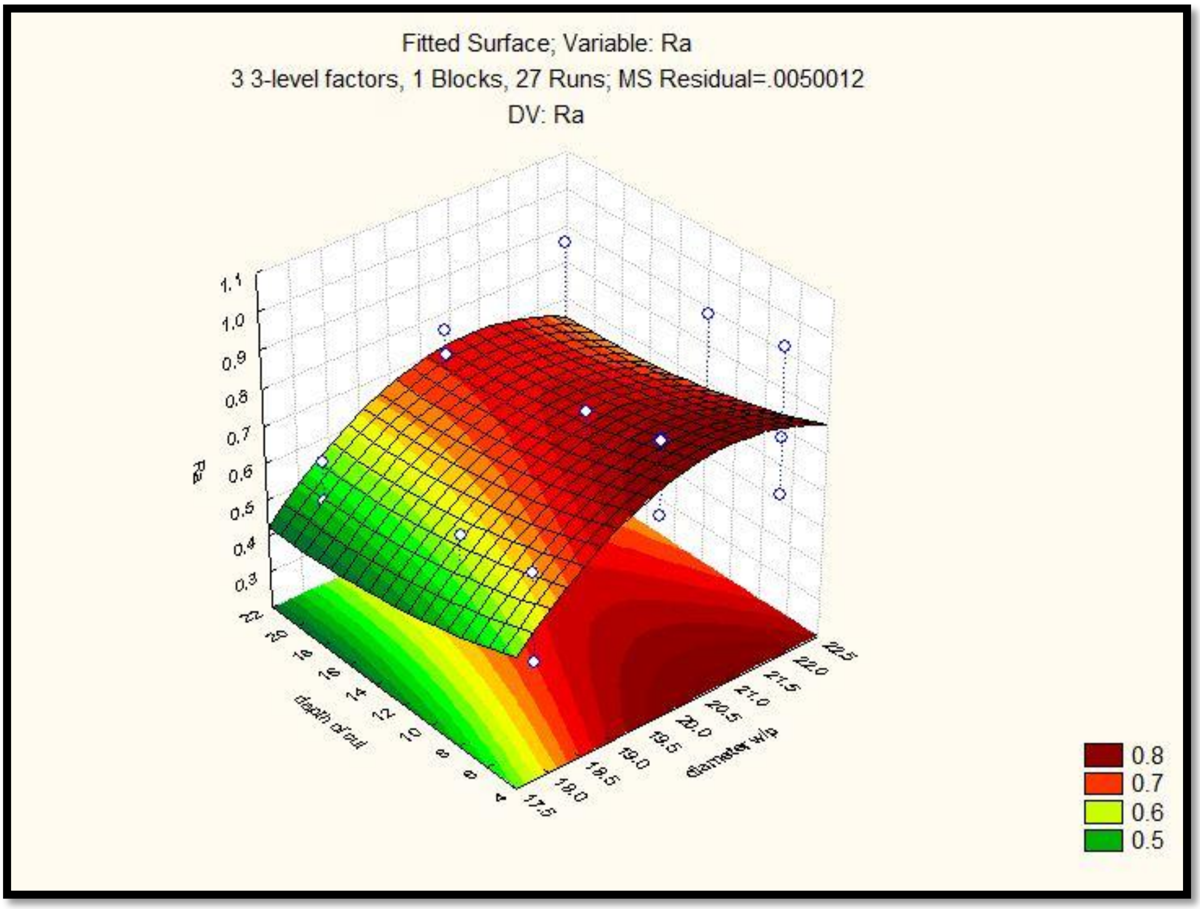

Figure 4.7: Surface plot of diameter w/p and depth of cut against generated Ra

Figure 4.7 showed relation between diameter of work piece and depth of cut to surface roughness with constant value of work speed. When applyed 80 rpm value of work speed, fine surface got from lower value of work piece's diameter and 14 µm to 20 µm for depth of cut.

During the experiment, some phenomena were occurred. First, chatter or unwanted vibrations have occurred on workpiece. The workpiece with different diameter were clamped into the clamping holder and it was rotated opposite direction with wheel rotation. This chatter occurs when there is contact between rotating wheel with rotating workpiece.

Besides that, experimental error also occurred in surface roughness measurement. This is because lack of apparatus condition that available in laboratory.

This phenomenon occurred when touched the stylus from Perthometer on the surface of workpiece to obtain the correct initial readings. These phenomena were effected the result of experiment and the analysis.

By referring to all the figures above, one can know the relation between the independent variables and the dependent variable in this experiment. Meanwhile, table 4.3 below show the regression coefficient for Surface Roughness experiment.

Table 4.3 : Regression table for Surface Roughness experiment

Factor	Regression Coefficient	Std Error	t(23)	p-level
Mean/intrc.	0.178611	0.207046	0.86267	0.397228
Work Speed ,s	-0.003847	0.000500	-7.68835	0.000000
Diameter w/p ,d	0.044444	0.010008	4.44092	0.000188
Depth of cut, x	-0.007151	0.002621	-2.72859	0.011975

By referring to general model equation (2.1) for factorial design,

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon$$

and the value of the regression coefficient were substituted into the model. In this case, x_1 is work speed, x_2 is diameter work piece and x_3 is the depth of cut. The model after the substitution were:

$$Ra = 0.178611 - 0.003847s + 0.044444d - 0.007151x$$

where ;

Ra is the surface rougness,

s is the work speed,

d is the diameter of work piece,

x is the depth of cut,

ϵ is the random disturbance or error.

Model 4.1 : Model equation for factorial design

4.3 DISCUSSION

The data that had been gathered are based on the experiment. And, even with all the precaution had been taken before starting the experiment, there is always a chance for an error occurs. Since this experiment is using the STATISTICA software to design the experiment, it had reduced the number and percentage of an error occurs. In addition, STATISTICA also had used in designing the experiment because it helped in making the experiment in systematically order. But, it was only for the general error regarding to the flow of the experiment. By using a machine for this experiment, it must to check the reliability and the repeatability of the machine. So, the data from the experiment need to use to analyze whether the machine was reliable or not. From the ANOVA table generated by the STATISTICA software, it can used to determine the machine reliability. Table 4.4 below showed the ANOVA table for the dependent variables in the experiment.

Factor	*SS*	*F*	*p*
Work Speed	0.426859	42.67524	0.000000
Diameter w/p	0.204510	20.44593	0.000015
Depth of cut	0.056653	5.66393	0.011246
Pure error	**0.100025**		
Total SS	0.788084		

R^2 = 0.87307 **Adj = 0.83499**

Table 4.4 : ANOVA table for Surface Roughness experiment

By referring to the table, notice that there are row of Pure Error and the value for the Pure Error. The value of the Pure Error used to determine the reliability of a machine that had used for each experiment. The par number for the Pure Error is 1 for every machine. And, from the table, it showe that the values in Pure Error were less than 1(<1). Therefore, it can said that the machine was reliable for this experiment.

To justify the normal distribution assumption, the Normal Probability plot used and the graph was generated from the STATISTICA software. Normal distribution was acceptable as the normal values were scattered nearby to the solid line. Figure 4.8 showed the Normal Probability plot for the dependent variables in the experiment.

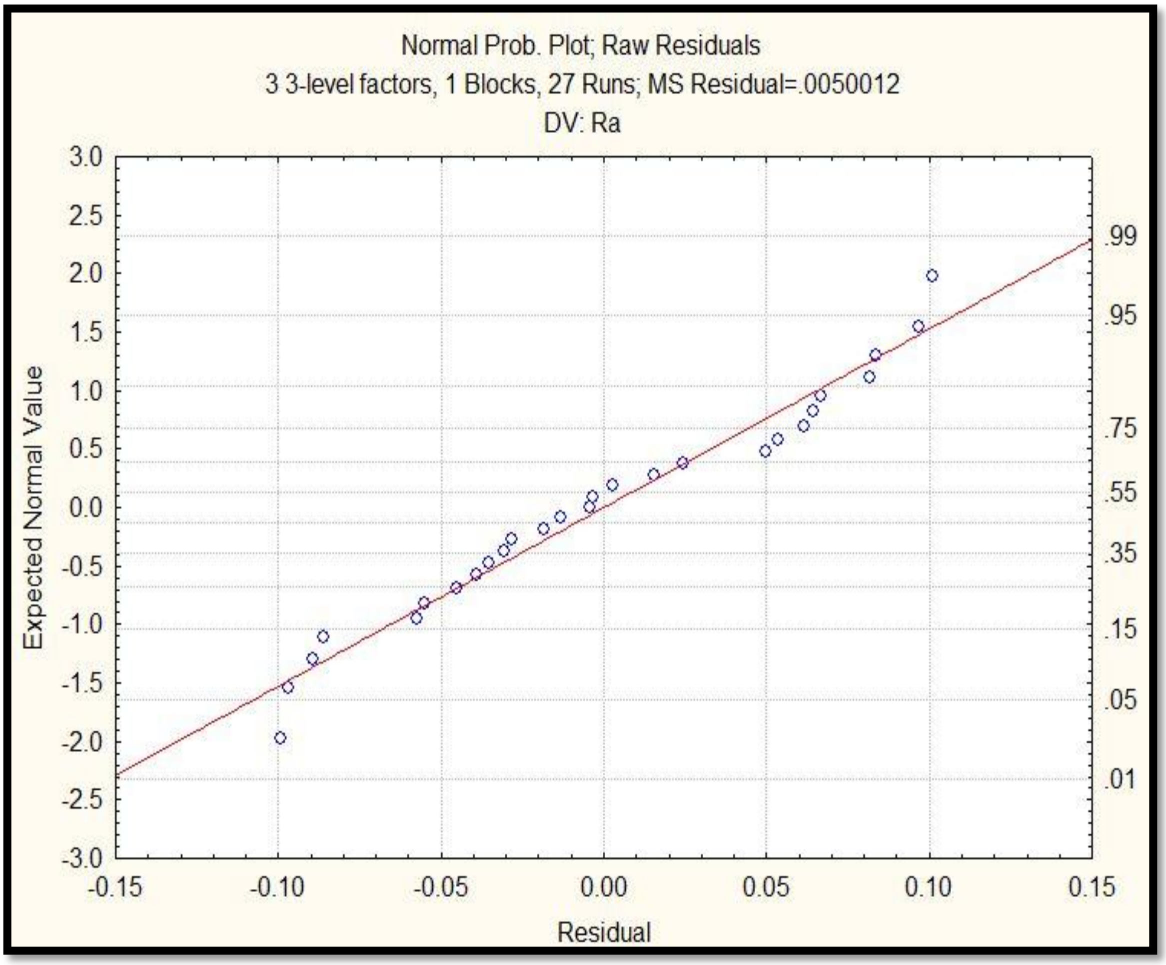

Figure 4.8: Graph Residual against Expected Normal value

From the Model 4.1 , there is ϵ which is the random disturbance or error. For calculation, the random disturbance was neglected since the data that had designed for the experiment in random. The STATISTICA software already made the data in systematically order after the randomization process had completed. The experiment need to ran according to the given order from STATISTICA software so that the random disturbance or error avoided.

This mathematical model based on the accuracy of the calculated value by comparing it with the experimental value. For this experiment, the surface roughness was related to the grinding machining parameters which is;

$$Ra = 0.178611 - 0.003847s + 0.044444d - 0.007151x$$

the diameter of workpiece, *d* gave more significant effect to the surface roughness compare to the other two parameters which is the work speed, *s* and depth of cut, *x* . This is because the regression coefficient value for the diameter of workpiece is higher compare to the other two parameters. It can be said that when the diameter of workpiece value are higher, the surface roughness would be higher.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In this chapter, the conclusion of the project was told according based on the project objectives and the project scopes. The recommendation also was in this chapter as the recommendation provided the information to improve the experiment in the future. This recommendation also were help other researcher to enhance the data and the result for this experiment.

5.2 CONCLUSION

As a conclusion, Cylindrical Grinding machine was succesful performed during the experinment. Based on the experimental result, it can be concluded that the work speed, diameter of workpiece and depth of cut affected the surface roughness used for machining operation. It is prove by the p-value from the effect estimate and ANOVA table .

For this experiment, the mathematical model can be generated which is Model 4.1 . By substituting the value of the parameter into the model, the calculated value can be created. From the calculated value, and comparing it with the experimental value, the accuracy of a model can be check. From the calculated value, the characteristic of a roughness can be predicted.

5.3 RECOMMENDATIONS

From the experiment and the analysis, there should be more addition to improve the experiment result and make the model developed become more reliable. Firstly, for the experiment, the number of the experiment and parameter range should be expanded for more valid conclusion. With the higher number of experiment, the experimental data would become more accurate approaching the predicted value. From that, the experimental data that will be used will increase the accuracy of the mathematical model that had been developed for the experiment. Furthermore, the mathematical model with high accuracy would become more reliable to calculate the experimental value for the parameters that should be investigate without conducting the experiment.

Secondly, the interaction between both of the dependent variable which is the value that had been measure after the experiment should be took into consideration. With the interaction, the analysis would provide different result from the result that is in this report. The interaction between independent variables also should be consider to get more valid data and result to generate more reliable model to demonstrate the characteristic of the surface roughness.

For the third recommandation is different material should be consider into this experiment. By adding different material type, the characteristic of the surface roughness can be clearly shown. Since every material has different properties, there might be a chance that the parameter that can influence the surface roughness will be changing according to the material type .

REFERENCES

Agarwal,S.,Venkateswara Rao, P. 2010. *Modeling and Prediction of Surface Roughness in Ceramic Grinding*. Ph.D Thesis. Bundelkhand Institute of Engineering & Technology, India.

Authorite. *Horizontal Band Saws.* (online) http://hubpages.com/hub/horizontal-band-saws. (12 April 2010).

Boubekri N.,Schneider M. H. and Asfour S.1992. Effects of Some Machining Variables in Lathe Facing Using a Profilometer to Measure Surface Roughness, **5**(2): 243-253.

Brinksmeier. E., Tonshoff, H.K., Inasaki, I., Peddinghans, J.1993. Basic Parameters in Grinding. Technical report . Ann. CIRP 42 (2) 795–799.

Dhinakarraj C.K., and Mangaiyarkarasi. P. 2003. *Prediction of Surface Roughness and Error in Cylindrical Grinding by Artificial Neural Network*. Ph.D Thesis. Adhiparasakthi Engineering College, Melmaruvathur.

Dubey, A. K.and V. Yadava 2008 Experimental Study of Nd : *YAG Laser Beam Machining An Overview*. Ph.D Thesis. Motilal Nehru National Processing Technology.

eFunda,.*AISI 1042*.(online) http://www.efunda.com/glossary/materials/alloys/ materials --alloys--steel--carbon_steel--aisi_1042.cfm (2 April 2010)

Huang Y. Y.,and Wu S. M.,1986, Grinding Surface Characterization by Cest.

Kalpakjian, et al.,2006. *Manufacturing Engineering and Technology* : Pearson Practice Hall

Li,G.F., Wang,L.S. and Yang,L.B. 2002. *Multi-Parameter Optimization of The Cylindrical Grinding Process*. Ph.D Thesis. Jilin University, China.

Loveless T.R.1993, *A study of the effects of abrasive flow finishing on various machined surfaces* .M.S. Thesis. University of Nebraska-Lincoln.

Mahr GmbH, Perthometer M1. *The Basic Model for Roughness Measurements*. (online)http://www.mahr.com/scripts/relocateFile.php?ContentID=4994&NodeID = 2451 &FileID=3340&ContentDataID=6513&save=0 (3 March 2010)

Manufacturelink, *Machining Processes-Cylindrical Grinding.* (online) http://www .manufacturelink.com.au/processes/machining-cylindrical-grinding.aspx (1 April 2010)

Marinescu, D, Hitchiner, M., Uhlmann,E., Inasaki,I. 2006. Monitoring of Grinding Process, Handbook of machining with grinding wheels.*CRC Press Taylor & Francis Group, Boca Raton, London & New York* .**72**.

Montgomery,D.C.,Runger, G.C. 2003. *Applied Statistics and Probability for Engineers:Third Edition*. New York: John Wiley & Sons, Inc.

Muthukrishnan N., 2008. Op*timization of machining parameters of Al/SiC-MMC with ANOVA and ANN analysis*. Ph.D Thesis. University of Aveiro, Campus, Santiago, Portugal.

Peters .J (1984), Contribution of CIRP research to industrial problems in grinding.Technical report. Ann. CIRP 32 (2) 451–468.

Pilgrim.G., *Mild Steel Properties. (online)* http://www.buzzle.com/articles/mild-steel-properties.html (31 March 2010)

Ratcliffe,B., *Cylindrical Grinding*. (online) http://ezinearticles .com/?Cylindrical Grinding&id=3564770 (28 March 2010)

Salmon and Stuart C. 1992. *Modern Grinding Process Technology*. McGraw-Hill.

Shaw M.C. 1996. *Principles of Abrasive Processing* : Oxford University Press, New York.

StatSoft.2010.,STATISTICA. (online) http://www .statsoft.com/unique -features/statistica-general-overview/ (27 March 2010)

Taraman K.1974. Multi Machining Output Multi- Independent Variable Turning Research by Response Surface Methodology. *Int. J. Prod. Res*.**12** (2):233-245.

Tlusty, G. 2000. *Manufacturing Processes and Equipment*, Upper Saddle River: Prentice Hall.

Wang,Y., Richard, C.M. Yam, Zuo, M.J, Tse,P. 2001. A comprehensive reliability allocation method for design of CNC lathes. *Elsevier.* **72** : 247–252.

Youssef, H.A., and Hassan El-Hofy, 2008. Machining Tools and Operations, Machining Technology. *CRC Press Taylor & Francis Group, Boca Raton, London & New York* :795–799.