# CYLINDRICITY OF WORKPIECE IN CONVENTIONAL LATHE MACHINE

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**UNIVERSITI MALAYSIA PAHANG**

**FACULTY OF MECHANICAL ENGINEERING**

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To my Beloved Father and Mother

**SHAHARUDIN BIN HASAN**
**NURULAIN BT ABDULLAH BAYANUDDIN**

To my siblings

**SUHAIL BIN SHAHARUDIN**
**SULHI BIN SHAHARUDIN**
**SYAHMI BIN SHAHARUDIN**
**NURUL ALIAH BT SHAHARUDIN**

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# ABSTRACT

Cylindrical aspects are one of the most fundamental traits in mechanical designs because they contribute significantly to various mechanical products such as shafts and revolving devices. Besides, it is crucial because it can determine the performance of the parts like the application used in transmission system. Basically, cylindricity can be defined as a condition of a surface of revolution in which all points on the surface are equidistant from a common axis. Cylindrical parts can be produced by using many machines and processes that are available. Numerous factors in manufacturing processes may cause a cylindrical part to depart from its ideal shape. It is essential to design proper experiment for assessing cylindricity. Therefore, the choice of the best combination parameters is important to control the cylindrical geometry. Turning operation using conventional lathe machine is used to produce this feature, while for evaluating the geometry, dial gauge is utilized. From the experiment, the best combination of parameter are feed rate of 0.15 mm/rev which had the biggest effect on cylindricity measurement followed by the cutting speed of 150 m/min and lastly is the depth of cut of 0.5 mm.

# ABSTRAK

Aspek kesilinderan adalah salah satu dari aspek asas dalam reka bentuk mekanikal kerana ia menyumbang kepada berbagai-bagai jenis produk mekanikal seperti *shaft* dan alat yang berputar. Selain itu, ia adalah penting untuk menentukan keupayaan sesuatu produk untuk berfungsi seperti yang terdapat pada sistem enjin. Secara umumnya, kesilinderan boleh diterjemahkan sebagai suatu keadaan dimana kesemua titik yang terletak di permukaan silinder berada dalam kedudukan yang sama jarak dari satu paksi yang sama. Komponen yang berbentuk silinder boleh dihasilkan dengan menggunakan pelbagai jenis mesin dan proses yang sedia ada. Terdapat banyak faktor dalam proses pembuatan yang boleh menyebabkan kepada sesuatu komponen yg berbentuk silinder lari dari bentuk yang ideal. Maka, adalah penting untuk merancang eksperimen yang sesuai untuk menilai kesilinderan sesuatu komponen. Oleh yang demikian, pemilihan kombinasi parameter yang terbaik adalah mustahak untuk mengawal geometri silinder. Proses larik menggunakan mesin larik biasa boleh digunakan untuk menghasilkan bentuk tersebut, manakala tolok dial pula dapat digunakan untuk menilai geometri silinder. Daripada eksperimen yang telah dijalankan, gabungan parameter yang terbaik adalah kadar potongan 0.15 mm/ rev yang memberi kesan terbesar kepada ukuran silinder, diikuti dengan halaju potongan 150 m/min dan terakhir adalah kedalaman sesuatu potongan 0.5 mm.

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| | |
|---|---|
| f | Feed Rate, mm/rev |
| d | Depth of Cut, mm |
| V | Cutting Speed, m/min |
| L | Length, mm |
| $D_0$ | Initial diameter, mm |
| n | Spindle speed, rev/min |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AISI | American Iron & Steel Institute |
| CMM | Coordinate Measuring Machine |
| CNC | Computer Numerical Control |
| FKM | Fakulti Kejuruteraan Mekanikal |
| UMP | Universiti Malaysia Pahang |

# CHAPTER 1

# INTRODUCTION

## 1.1 OVERVIEW

Cylindrical features are one of the most basic features in mechanical designs because they contribute significantly to various mechanical products. Generally, cylindricity is a three dimensional tolerance that controls how much a feature can deviate from a perfect cylinder. But, basically, cylindricity is defined as a condition of a surface of revolution in which all points of the surface are equidistant from a common axis. There are many misconceptions surround cylindricity. This is because cylindricity is very difficult to characterize in the presence of unrelated signals in any data such as shape distortions produced by tilt and eccentricity mask the expected shape of the workpiece, since the knowledge of the measurement of cylindricity profiles is relatively limited.

Products with cylindrical surfaces are manufactured in many industries and useful in many applications. For examples, in paper, chemical, steel, heating or shipping industries require regular estimations of cylindricity profiles during the production process. One of the most often geometrical elements that been produced details are transmission systems, precision gauges and revolving devices. In most cases they represent very responsible part of the machine or been used in automotive sectors and therefore they require very thorough, full accuracy analysis. It is not enough just to measure their diameters or positions, but it is crucial to measure their out-of-roundness as well.

Nowadays, cylindrical parts can be produced by using many machines or process that are available in industries such as lathe machine and Computer Numerical Control machine (CNC) in turning process, as well as cylindrical grinder in grinding process. Cylindricity is found by taking numerous diameter measurements or slices and comparing the highest diameter measurement to the lowest diameter measurement across the entire rod face. The range between the maximum and minimum diameter measurements is the value for cylindricity.

Determining the cylindricity of any part can be quite time consuming when using conventional measuring devices such as dial indicators, Pi Tapes and micrometers. The data collected will probably be inaccurate and misleading due to the limitations of the measurement tools themselves. Advanced electronic measuring system such as Coordinate Measuring Machine (CMM) can produce accurate picture of the exact geometric shape of a cylinder. The pictures can help to diagnose problem and help to ensure that new cylinder will be successful in use.

## 1.2 PROBLEM STATEMENT

A huge number of mechanical parts embrace of cylindrical features. A vital geometric characteristic that is used to control form and function of cylindrical features is cylindricity. Significant and serious error associated with this characteristic may result in the breakdown or failure or imperfect functioning of the corresponding part. The accuracy of cylindricity measurement can leads to strict tolerancing and consequently, to avoid rejections of valid specimens which are very costly. In material removal process which is in turning operation specifically, cylindrical shaft can be developed using conventional lathe machine by controlling some parameters to get accurate geometry. Cylindricity of workpiece is crucial because it can determine the performance of the part. Besides that, defects such as wear and tear can be prevented and also the lifespan of the part or component attach to it (if any) can last longer.

## 1.3 PROBLEM OBJECTIVES

i) Investigating the cylindrical effect of different cutting speed, depth of cut and feed rate on the workpiece of medium carbon steel in conventional lathe machine.

ii) Evaluating the geometry of the machined workpiece using dial gauge and analyzing the result to determine the best combination of cutting parameters.

## 1.4 SCOPE OF STUDY

The scope of the study for this project is to conduct experiments in order to investigate the cylindricity of workpiece. The material used for this investigation is medium carbon steel. The accuracy of cylindricity measurement can be controlled by many parameters like feed rate, cutting speed, depth of cut and type of coolant. In this project, the investigation is based on three parameters; cutting speed, feed rate and depth of cut which are essential in turning process. After the turning operation, the geometry is to be evaluated and analyzed.

## 1.5 PROJECT BACKGROUND

This project is to investigate the cylindricity of workpiece using medium carbon steel. AISI 1045 is selected as the raw material which is in solid bar shape. The dimensions are: 150mm in length and 40mm in diameter. There are three parameters that have been identified and will be used in this experiment, which are the cutting speed, depth of cut and feed rate. Three different values are specified for each parameter. Taguchi’s approach is used for determining the number of experiment that will be conducted in this project. This type of method is based on the numbers of level design and the number of factor that have been specified. Power saw machine is to be used to cut the raw material into desired dimension. Other than that, conventional lathe machine is to be used for turning process. The cutting tool that will be used in this experiment is carbide insert. Another device that will be used for evaluation of cylindricity is the dial gauge. Lastly, the data that have been collected from the experiment will be analyzed by plotting graphs using Excel.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter discussed the general information of medium carbon steel and its properties, cutting tool, lathe machine, turning process, as well as coordinate measuring machines which are directly incorporated in this project.

## 2.2 STEEL

Metals and alloys have many useful engineering properties and so have extensive application in engineering designs. Iron and its alloys (principally steel) account for about 90 percent of the world's production of metals mainly because of their combination of good strength, toughness and ductility at a relatively low cost. Each metal has special properties for engineering designs and is used after a comparative cost analysis with other metals and materials. (Smith, 2006)

Steel is an alloy of iron that contains carbon ranging by weight between 0.02% and 2.11%. It often includes other alloying ingredients as well: manganese, chromium, nickel and molybdenum; but it is the carbon content that turns iron into steel. There are hundreds of compositions of steel available commercially. Generally, they can be grouped into four categories which are plain carbon steels, low alloy steels, stainless steels and tool steels. (Groover, 2007)

Only the first category will be discussed here. Plain carbon steels are containing manganese as an alloying enhances strength and hardness that ranges between 0.30 and 0.95 percent. Plain carbon steels have three classes: low carbon steels (less than 0.20% carbon content), medium carbon steels (0.20% to 0.50% carbon content) and high carbon steel (greater than 0.50% carbon content). As the carbon content of the plain carbon steels is increased, the steels become stronger but less ductile. Plain carbon steels have been used in industry for strengthen parts and often used in forgings, gears, and other parts for automotive and structural applications. (Smith, 2006)

### 2.2.1 Medium Carbon Steel

Groove, 2007 has stated that carbon steel with carbon content ranging 0.20% to 0.50% is termed as medium carbon steel. They are specified for application requiring higher strength than the low carbon steels such as shafts and gears in automotive field also crankshafts and connecting rods in machinery components. Medium carbon steels are often heat treated to obtain higher strength, such as by quenching and then tempering.

Some improvements and developments have been made due to some weaknesses because of low carbon content. Therefore, medium carbon and high carbon steel have more demand in market compare to low carbon steel. It has been known that medium carbon steels are mostly used for simple applications; however, new applications have been developed for which good and better formability is required (Herreraa et al, 2006). Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing.

## 2.3 CUTTING TOOL

There are many types of tool material, ranging from carbide inserts (Figure 2.1), high-carbon steel to ceramics and diamonds, are used as cutting tools in today's metalworking industry. It is important to be aware that differences do exist among tool materials, what these differences are, and the correct application for each type of material.

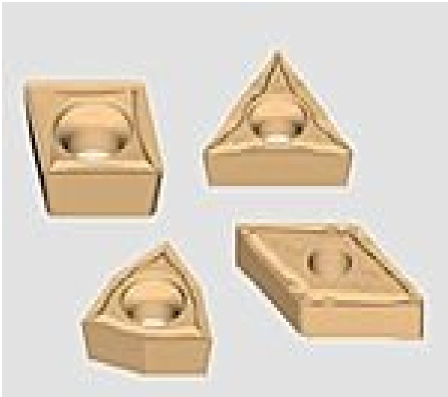


**Figure 2.1:** Carbide inserts

Source: www.directindustry.com (2009)

The various tool manufacturers assign names and numbers to their products. Many of these names and numbers may appear to be similar, but the applications of these tool materials may be entirely different. In most cases the tool manufacturers will provide tools made of proper material for each given application. In some particular applications, a premium or higher-priced material will be justified.

This does not mean that the most expensive tool always the best tool. Cutting-tool users cannot afford to ignore the constant changes and advancements that are being made in the field of tool material technology. When a tool change is needed or anticipated, a performance comparison should be made before selecting the tool for the job. The optimum tool is not necessary the least expensive or the most expensive, and it are not always the same as the tool that was used for the job last time. The best tool is the one that has been carefully chosen to get the job done quickly, efficiently and economically.

A cutting tool must have the following characteristics in order to produce good quality and economical parts:

a) Hardness: hardness and strength of the cutting tool must be maintained at elevated temperature,

b) Toughness: toughness of the cutting tools is needed so that tools do not chip or fracture, especially during interrupted cutting operations,

c) Wear resistance: wear resistance means the attainment of acceptable tool life before tools need to be replaced.

The materials from which the cutting tools are made are all characteristically hard and strong. A wide range of tool materials are available for machining operations. (Nelson, 2001)

### 2.3.1 Cemented-Carbide Toolbits

According to Krar et al, 2005, cemented-carbide toolbits are capable of cutting speeds three to four times those of high-speed steel toolbits. They have low toughness but high hardness and excellent red-hardness qualities (red hardness is the ability to maintain a sharp cutting edge even when it turn red because of the high heat produced during the cutting operation).

Cemented carbide consists of tungsten carbide sintered in a cobalt matrix. Sometimes, other materials such as titanium or tantalum may be added before sintering to give the material the desired properties. Straight tungsten carbide toolbits are used to machine cast iron and nonferrous materials. Since they crater easily and wear rapidly, they are not suitable for machining steel. Crater-resistant carbides, which are used for machining steel, are made by adding titanium and/or tantalum carbides to the tungsten carbide and cobalt. Different grades of carbides are manufactured for different work requirements. Those used for heavy roughing cuts contain more cobalt than those used for finishing cuts, which are more brittle and have greater wear resistance at higher finishing speeds.

## 2.4 LATHE MACHINE

A lathe is a machine tool which spins a block of material to perform various operation such as facing, taper turning, treading, chamfering drilling, boring, knurling of deformation with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation. Lathes are manufactured in a wide range of sizes. The average metric lathe used in school shops may have a 230 to 330 mm swing and have a bed length of from 500 to 3000 mm.

The main parts of the lathe machine as shown in Figure 2.2 are bed, headstock, quick-change gearbox, carriage and tailstock. Besides that, many lathe accessories are available to increase the versatility of the lathe and the variety of work that can be machined such as lathe centers, chucks, collets, mandrel, and lathe dogs. Overall, lathe is the most commonly used machine in the industry because it can be used for many types of operations. Modern lathe machines have come with other types such as the engine, turret, single and multiple-spindle automatic, tracer and now computer-numerical-controlled. (Krar et al, 2005)

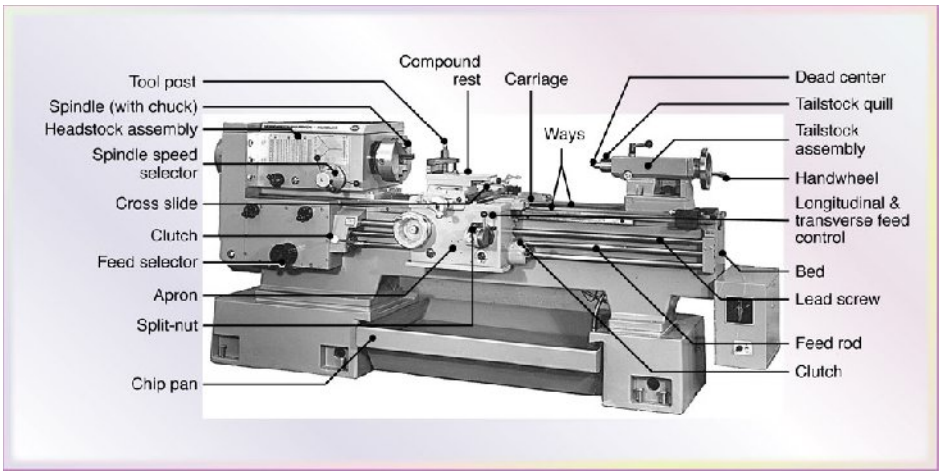



**Figure 2.2:** Parts of conventional lathe machine

Source: Kalpakjian et al. (2007)

### 2.4.1 Turning

Turning operation as shown in Figure 2.3 is a metal-cutting process used for the generation of cylindrical surfaces. Normally the workpiece is rotated on a spindle and the tool is fed into it radially, axially or both ways simultaneously, to give the required surface. In its basic form, it can be defined as the machining of the outer surface. The term “turning” in general sense, refers to the generation of any cylindrical surface with a single-point tool. More specifically it is often applied just to the generation of external cylindrical surfaces oriented primarily parallel to the workpiece axis.

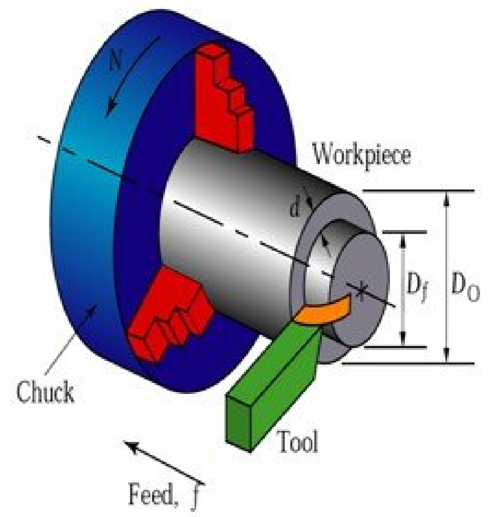



**Figure 2.3:** Turning operation showing depth of cut, *d*, and feed, *f*.

Source: Kalpakjian et al. (2007)

The cutting characteristics of most turning applications are similar. For a given surface only one cutting tool is used. This tool must overhang its holder to some extent to enable the holder to clear the rotating workpiece. (Nelson, 2001)

### 2.4.2 Cutting Conditions

After deciding on the cutting tool and the machine tool, the following cutting condition should be in consideration:

a) Cutting speed, *V*

b) Feed rate, *f*

c) Depth of cut, *d*

The choice of these cutting conditions will affect the productivity of the machining operation in general and the quality of the product in particular. Therefore, these elements must be carefully chosen for each operation.

Cutting speed can be defined as the rate at which a point on the work circumference travels past the cutting tool. It is usually denoted by '*V*' and the unit can be in m/min or in/min. Industry worldwide need machining operations be performed as quickly as possible; therefore, the perfect cutting speed must be used suitable to the type of material cut. If the value of cutting speed is differ from the required material properties, errors and damage may occur and resulting in low production rate. However, value of cutting speed may also varied according to suit factors like the machine's condition, the type of work material and sand or hard spots in the metal.

Dudzinski, 2002 stated that cutting speed can influence on chip formation, cutting forces, surface quality and residual stress. When applying higher cutting speeds, the shear angle increases and thus resulting in a decrease of chip thickness and also continuous chip is generated. Similarly, increasing cutting speed leads to reduce cutting forces and better surfaces. Moreover, an improvement of the surface quality is achieved by the increase of the cutting speed.

Feed rate is always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in millimeter (of tool advance) per revolution (of the spindle). Before machining, make sure the suitable and recommended feeds for cutting various materials is checked, so that the turning operation will run smoothly and success.

Depth of cut is the thickness of the layer being removed from the workpiece or the distance from the uncut surface of the work to the cut surface, expressed in millimeter. It is important to note, though, that the diameter of the workpiece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

When machining a workpiece, only one roughing and one finishing cut was taken. There are several factors that influence the depth of a rough turning cut such as the condition of the machine, the type and shape of the cutting tool being used, the rigidity of the workpiece, the machine and the cutting tool, and the feed rate. (Krar et al, 2005)

## 2.5 COORDINATE MEASURING MACHINE

A coordinate measuring machine (CMM) as in Figure 2.4 consists of a contact probe and a mechanism to position the probe in three dimensions relative to surfaces and features of workpart. CMMs were developed to speed up the process of measuring parts produced. As the lathe machine is to manufacture, the CMM is to inspection. It can measure almost any shape with extreme accuracy and without the use of special gauge. (Groove, 2007)


**Figure 2.4:** Coordinate measuring machine

### 2.5.1 Application of CMM

CMM is computer controlled which permits the CMM to accomplish more sophisticated measurements and inspections, such as determining center location of a hole of cylinder, definition of plane, measurement of flatness of a surface or parallelism between two surface and measurement of an angle between two planes. These measuring machines can be installed on production lines to automate inspection, minimize operator error, and provide uniform part quality. (Krar et al, 2005)

In a CMM, the probe is fastened to a structure that allows movement of the probe relative to the part, which is fixture on a worktable connected to the structure. The structure must be rigid to minimize deflections that contribute to measurement errors. An important aspect in a CMM is the contact probe and its operation. The probes have a sensitive electrical contact that emits a signal when the probe is deflected from its neutral position in the slightest amount. On contact, the coordinate positions are recorded by the CMM controller, adjusting for overtravel and probe size.

### 2.5.2 Advantages

Advantages of using CMM over manual inspection methods include:

a) Higher productivity – CMM can perform complex inspection procedures in much less time than traditional manual methods;

b) Greater inherent accuracy and precision than conventional methods; and

c) Reduced human error through automation of the inspection procedure and associated computations.

## 2.6 DIAL GAUGE

The dial gauge is one of measuring instrument that is frequently used in industry and mechanical processes. This device is used to accurately measure small linear distance. It is also known as dial indicator, probe indicator of as a clock. This device is named so because of the measurement results are shown in a magnified way by means of a dial.

**Figure 2.5:** The dial gauge

Source: www.findtheneedle.co.uk

The dial gauge typically consist of a graduated dial and needle to record the minor changes, with a smaller embedded clock face and needle to record the number of needle rotations on the main dial. The dial has fine gradations for precise measurement. The spring-loaded probe moves perpendicular to the object that is being tested. This can be seen in Figure 2.5.

### 2.6.1 Application of Dial Gauge

Measuring using the dial gauge is categorized as the conventional of traditional method. In this method, the point on the object tested which set as a reference is called intrinsic datum system. These methods are very convenient for approximation of the true out-of-roundness value.

The dial gauge can be used in automotive field like to check for run out when fitting a new disc on a disc brake. Run out can rapidly ruin the disc if it exceeds the specified tolerance. In a quality environment area, the consistency and accuracy can be checked in the manufacturing operation. Furthermore, initially set up or calibrate or align a machine using this device is prior to a production run. Besides that, dial gauge can be used in the areas other than manufacturing where accurate measurements need to be recorded.

## 2.7 CONCLUSION

This chapter successfully discussed on the material used in this project, the suitable cutting tool, the processes needed and the machine requirements and properties. The cutting speed plays an important role in turning process where it may influence on chip formation, cutting force and surface quality. Hence, it is essential to select the suitable cutting speed in order to control the parameter that has been discussed earlier. Besides that, it will help in some sort of other way to reduce expenses of the project.

# CHAPTER 3

# METHODOLOGY

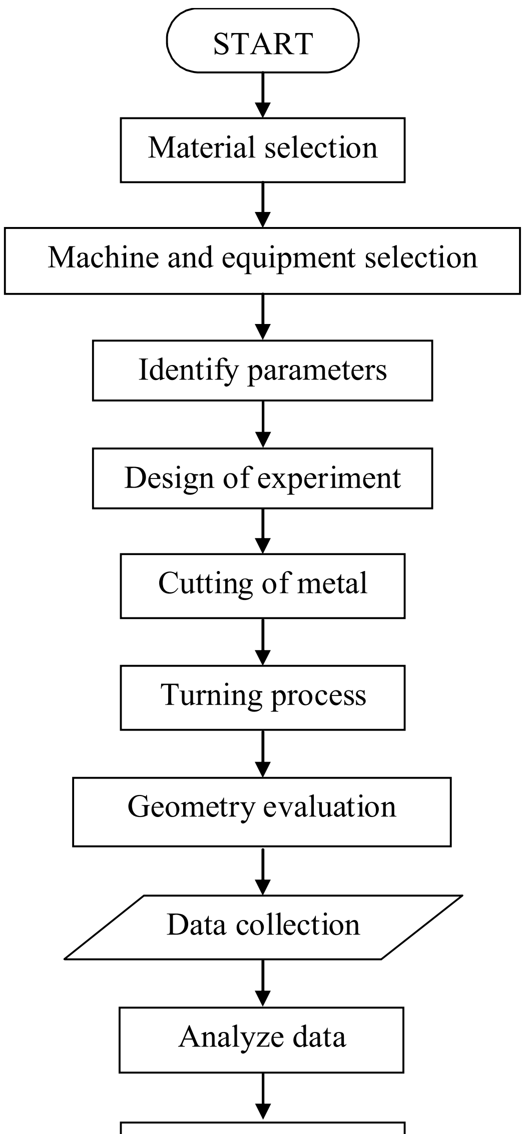
## 3.1 INTRODUCTION

This chapter presents the overall methodology for cylindricity of workpiece in conventional lathe machine. The whole process of this project can be categorized into three main parts.

The very first part is the selection process. This part consists of two operations which are material selection and machine and equipment selection.

The second part is the process operations that are going to be computed. They are the cutting process of the material, turning process and lastly are the geometry evaluation process.

The final part describes how to collect, compare, analyze and interpret data. Tabulation data was given for further analysis. Before explaining details on the methods used, flowchart as in Figure 3.1 was made to show a details information for the overall experiment. For further explanation of the flow chart in Figure 3.1 will be discussed in the next substopic.



## 3.2 MATERIAL SELECTION

The important feature of this project is to select the appropriate material. So, in this experiment, the material that will be used is medium carbon steel, AISI 1045 which is suitable for application of shaft usually employed in automotive industry. After materials have been selected, the material is to be cut in order to get three specimens using power saw machine (Figure 3.2) with the dimension of the each specimen is specified, 40 mm in diameter and 150 mm in length (Figure 3.3).


**Figure 3.2:** Power saw machine

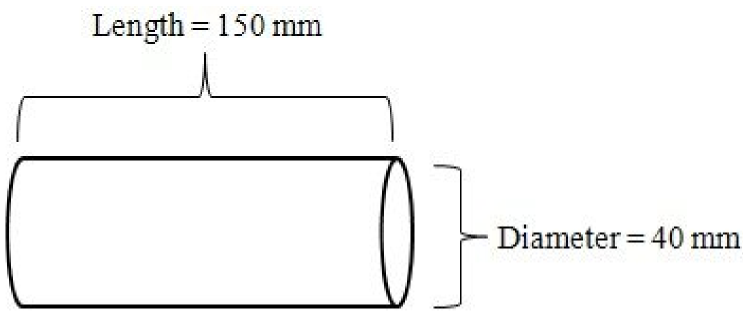



**Figure 3.3:** Material dimension

## 3.3 MACHINE AND EQUIPMENT SELECTION

Two main machines are to be used in this project which is power saw machine (Figure 3.2) and conventional lathe machine (Figure 3.4) that are available in FKM, UMP laboratory.

The conventional lathe machine is used to perform turning operation based on the first objective where investigation needs to be made in order to observe the effect of different cutting speed and depth of cut on the specimen. The cutting tool has been specified which is cemented-carbide will be used as the toolbit/ insert. This type of toolbit is chosen because it is capable of cutting speeds three to four times those of high-speed steel toolbits. Besides that, it has high hardness and able to maintain a sharp cutting edge.

The dial gauge is employed to inspect the specimens that have been undergone the turning process. The function of inspection is to get the measurement of the specimens' shape. Additional equipment such as Vernier caliper and centre drill will be used in the experiment. The caliper is used to measure the workpiece and the centre drill is used to drill a small hole. This is to be done because it provides a support and align the workpiece using the tailstock.

## 3.4 DESIGN OF EXPERIMENT

Taguchi's approach is selected for determining the number of experiment that will be conducted in this project due to some problem encountered such as material shortage and the condition of laboratory. This type of method is based on the numbers of level design and the number of factor that have been specified.

It is a technique to lay out experiment plan in most logical, economical and statistical way. Using the Minitab software, the experiment sequence can be computed by setting the level of design of 3 and the number of factor of 3. Then, two types of run can be chosen which are 9 runs or 27 runs. After 9 runs are preferred, the orthogonal array is published as in Table 3.1.

**Table 3.1:** Orthogonal array design table

| Run | A | B | C |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 |
| 3 | 1 | 3 | 3 |
| 4 | 2 | 1 | 2 |
| 5 | 2 | 2 | 3 |
| 6 | 2 | 3 | 1 |
| 7 | 3 | 1 | 3 |
| 8 | 3 | 2 | 1 |
| 9 | 3 | 3 | 2 |

From the Table 3.1, A, B and C are represented as cutting speed, depth of cut and feed rate, respectively. The value of 1, 2 and 3 are the different value of the parameters.

## 3.5 TURNING PROCESS

The conventional lathe machine as shown in the Figure 3.4 will be used in turning process. In this operation, three parameters have to be controlled. Different cutting speed (m/min), depth of cut (mm) and feed rate (mm/rev) is used during the operation. The values of the parameters that are shown in Table 3.2 are taken from book written by Kalpakjian et al, 2007.

**Figure 3.4:** Conventional lathe machine

To begin the operation, the workpiece need to be clamped and tighten it. The speed of the spindle is to be set by calculation based on the cutting speed. Appropriate safety equipment need to be put on when operating the lathe machine to prevent any injury such as goggle and tidy attire and. The experiment is run by referring to the following table:

**Table 3.2:** Machine parameters

| **Machine parameters** | **Level** | | |
|---|---|---|---|
| | **Low** | **Medium** | **High** |
| Cutting speed (m/min) | 75 | 113 | 150 |
| Feed rate (mm/rev) | 0.15 | 0.45 | 0.75 |
| Depth of cut (mm) | 0.5 | 1.5 | 3.0 |

Source: Kalpakjian et al. (2007)

## 3.6 GEOMETRY EVALUATION IN DIAL GAUGE

After performing the turning operation, the cylindricity evaluations of the specimen is done using the dial gauge. The specimen is then clamped in the CNC machine where the probe of the dial is attached to the magnetic stand and then it is fastened to a structure that allows movement of the probe to measure the shape geometry as shown in Figure 3.5. The points on the surface of specimen called intrinsic datum system will be used in the experiment where the points are actually acted as the datum. The location coordinates of the probe can be accurately recorded as it contacts the part surface to obtain part geometry data. In order to minimize deflections that contribute to measurement error, the position of the workpiece must be located properly.

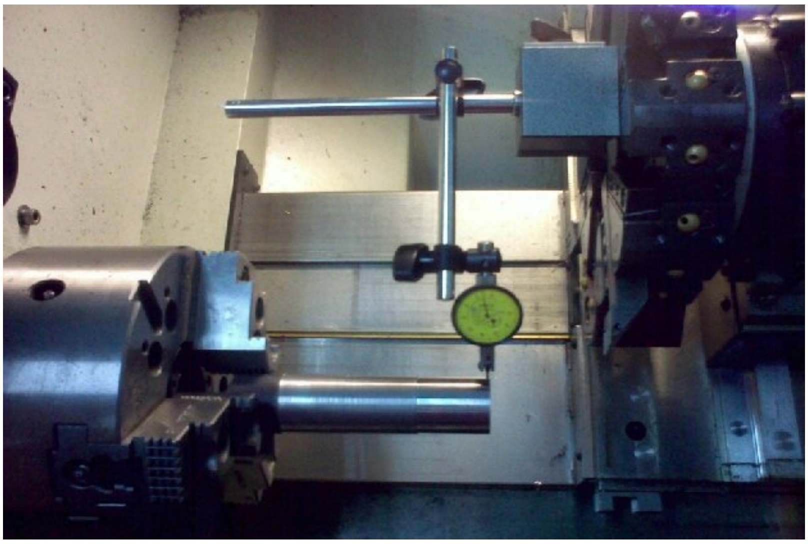


**Figure 3.5:** The dial gauge with magnetic stand attached to CNC machine and the workpiece is clamped at the chuck.

## 3.7 MEASURING TECHNIQUES

Each workpiece consist three steps. Three points at every step are taken during the evaluation. Thus, there are nine points for every workpiece. The measurement is then taken at four quadrants by finishing one quadrant at a time. After one quadrant has been completed, the chuck is rotated to measure the next quadrant. These measuring techniques are illustrated in Figure 3.6 and Figure 3.7.

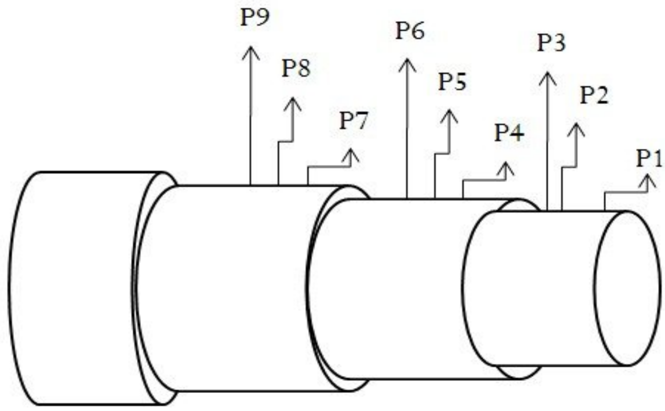



**Figure 3.6:** The measuring position on the workpiece

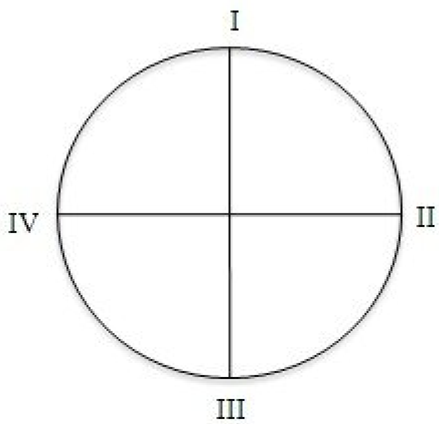



**Figure 3.7:** The position of four quadrants

## 3.8 DATA COLLECTION AND INTERPRETATION

In this project, calculation procedure may take place before and after the experiment. The cutting speed is converted to spindle speed by calculation before experiment session as it is required during the machine setting process. After experiment, another calculation may take place when average values are needed in the analysis stage.

### 3.8.1 Cutting Speed

Mild steels are readily machinable at the cutting speed range of 75m/min to 215 m/min with using carbide inserts. Due to limitation on the current lathe machine, only three cutting speed were chosen based on the machine spindle speed availability. The spindle speed was calculated by using the following Formula 3.1:

$$n = \frac{\quad}{\times \; {}_{0}} \qquad (3.1)$$

Where $V$ = cutting speed, m/min

$\pi$ = mathematical constant value approximately equal to 3.14159.

$D_0$ = initial diameter of mild steel bar, in meter.

$n$ = spindle speed available, rpm

The cylindricity measurements that are obtained from dial indicator are recorded and analyzed using suitable statistical method. Nine points on the surface of workpieces are taken to check the cylindricity. After that, comparison of the results is observed between the specimen that undergoes the different cutting speed, feed rate and depth of cut. Lastly, the interpretation of the overall data can be made based on the comparisons technique and analysis method and can be logged in Chapter 4.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 INTRODUCTION

Chapter 4 is generally discuss the results obtained throughout the experimental research analysis on the cylindricity measurement (µm) using the dial gauge which are found after a period of machining process (turning).

## 4.2 EXPERIMENTAL RESULTS

Measurement at 9 points at each quadrant is taken using the dial gauge. The data obtained from the dial gauge is collected and recorded as in the following Table 4.1 until Table 4.3.

**Table 4.1:** Dial gauge readings of workpiece no. 1 (µm)

| Quadrant | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 |
|---|---|---|---|---|---|---|---|---|---|
| I | 82 | 88 | 78 | -44 | -49 | -54 | 12 | 2 | 0 |
| II | -30 | -86 | -144 | -65 | -131 | -189 | -60 | -118 | -198 |
| III | -2 | -4 | -36 | -52 | -84 | 79 | -24 | -76 | -98 |
| IV | 36 | 84 | 95 | 16 | 60 | 104 | 143 | 116 | 105 |

**Table 4.2:** Dial gauge readings of workpiece no. 2 (µm)

| Quadrant | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 |
|---|---|---|---|---|---|---|---|---|---|
| I | 22 | 10 | 26 | 22 | 10 | 32 | 9 | 46 | 20 |
| II | -18 | -12 | -12 | 2 | -13 | -6 | -10 | -14 | -22 |
| III | 32 | 8 | -2 | 13 | -5 | -38 | -2 | 12 | 11 |
| IV | 16 | 17 | 40 | -1 | 39 | 89 | -2 | 22 | 28 |

**Table 4.3:** Dial gauge readings of workpiece no. 3 (µm)

| Quadrant | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 |
|---|---|---|---|---|---|---|---|---|---|
| I | 2 | 4 | 6 | 7 | 14 | 30 | 2 | 32 | 36 |
| II | -4 | -16 | -18 | -2 | 0 | -2 | 0 | -4 | 2 |
| III | -8 | -13 | -9 | 4 | -4 | 0 | -18 | -20 | -16 |
| IV | 8 | 12 | 20 | -5 | 10 | 20 | 17 | 17 | 35 |

## 4.3 ANALYSIS OF CYLINDRICITY

### 4.3.1 Analysis of Workpiece No. 1

For the first workpiece, the following parameters are used:

i) Spindle speed = 600 rev/min

ii) Feed rate = 0.15 mm/rev

iii) Depth of cut = 0.5, 1.5, 3.0 mm

Based on the reading obtained from the dial gauge, the cylindricity can be observed by generating line graphs. Figure 4.1 until Figure 4.6 are the graphs for analyzing the first workpiece.

By comparing Figure 4.1 and Figure 4.2, Figure 4.1 shows better trend where the points are fairly distributed in quadrant I and III; whereas for Figure 4.2, the trend is gradually diverged on quadrant II and IV. No extreme point is observed.

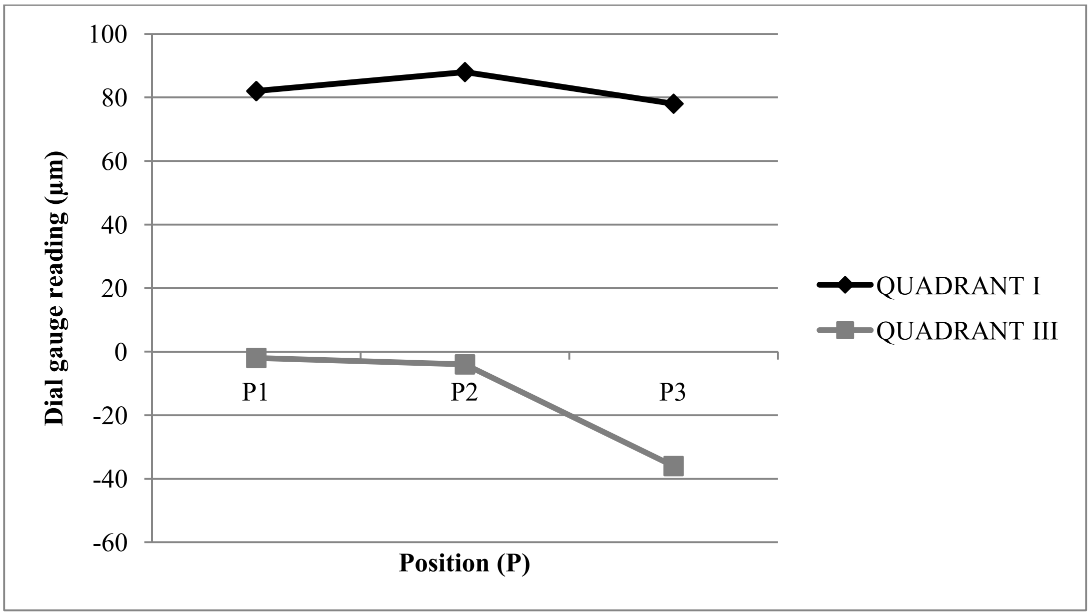



**Figure 4.1:** Graph of dial gauge reading vs. position 1, 2 and 3 for quadrant I and III for workpiece no. 1

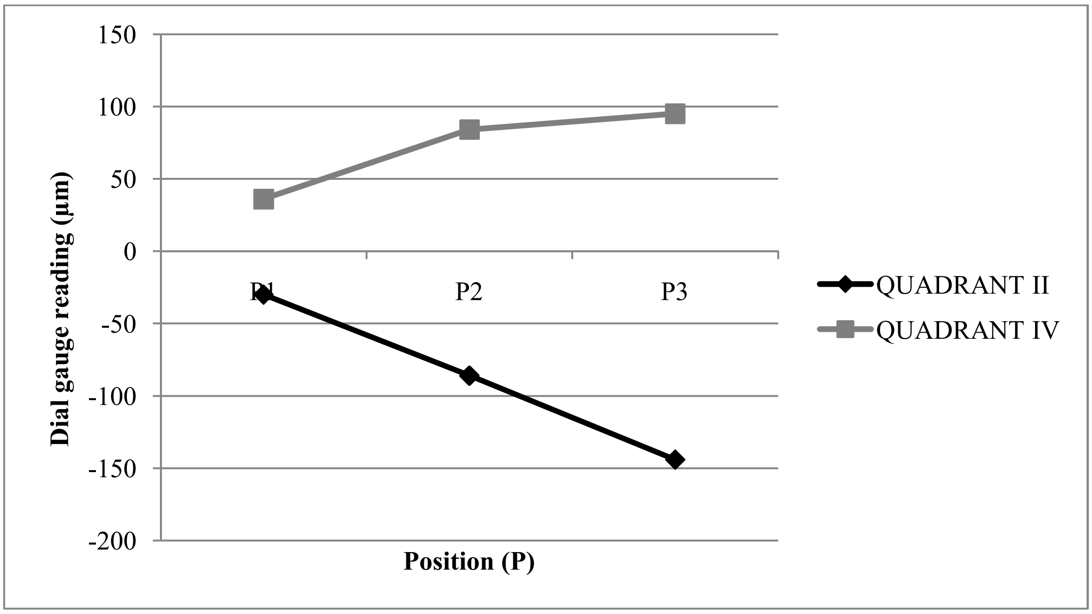



**Figure 4.2:** Graph of dial gauge reading vs. position 1, 2 and 3 for quadrant II and IV for workpiece no. 1

Referring to Figure 4.3 an extreme point is observed due to the surface texture at that particular point is rough compared to the other position. This maybe caused by the vibration of the spindle which was found that the amplitude and frequency gained had strong effects on surface topography. The vibration of spindle happened due to damaged or unbalanced jaws. For Figure 4.4, the gauge values give shape of the graph to diverge proportionally.

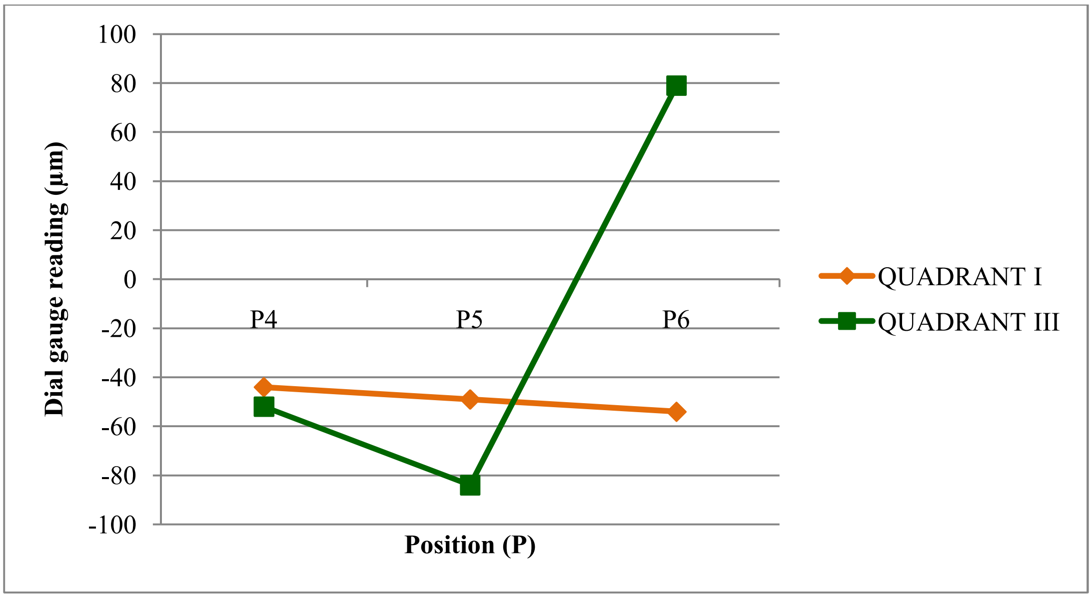



**Figure 4.3:** Graph of dial gauge reading vs. position 4, 5 and 6 for quadrant I and III for workpiece no. 1

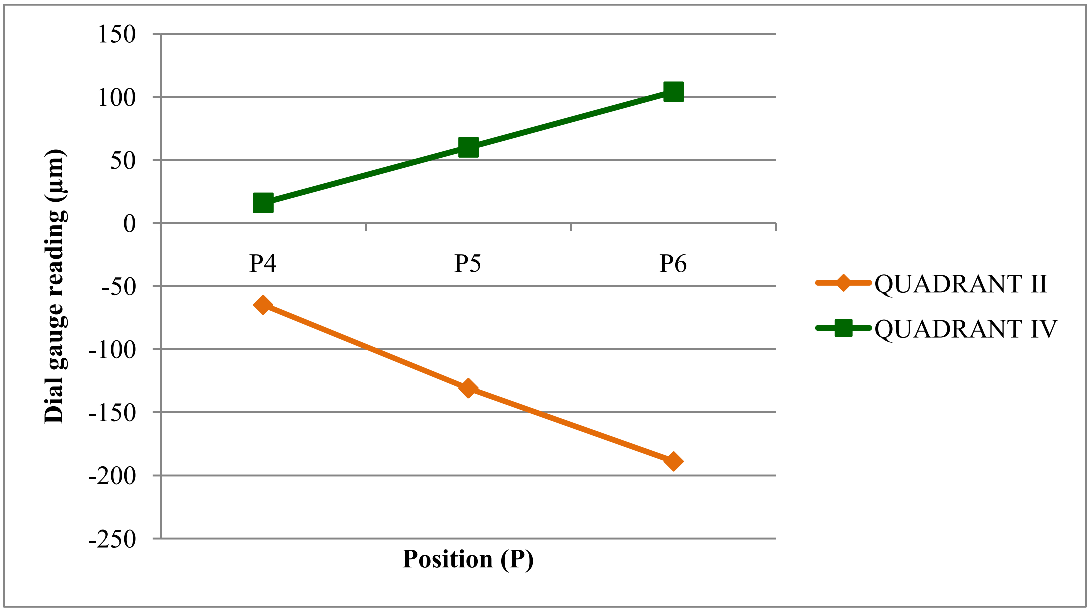



**Figure 4.4:** Graph of dial gauge reading vs. position 4, 5 and 6 for quadrant II and IV for workpiece no. 1

The points in Figure 4.5 and 4.6 are located at the last step of the workpiece. The tendency of the graph is more or less the same where the difference in between quadrant I and II with quadrant II and IV in both graphs is increased. From the literature study, it is better to use the low depth of cut with higher cutting speed because this will prevent the formation of build-up-edge and also it will be aiding the process by yielding a better surface finish.

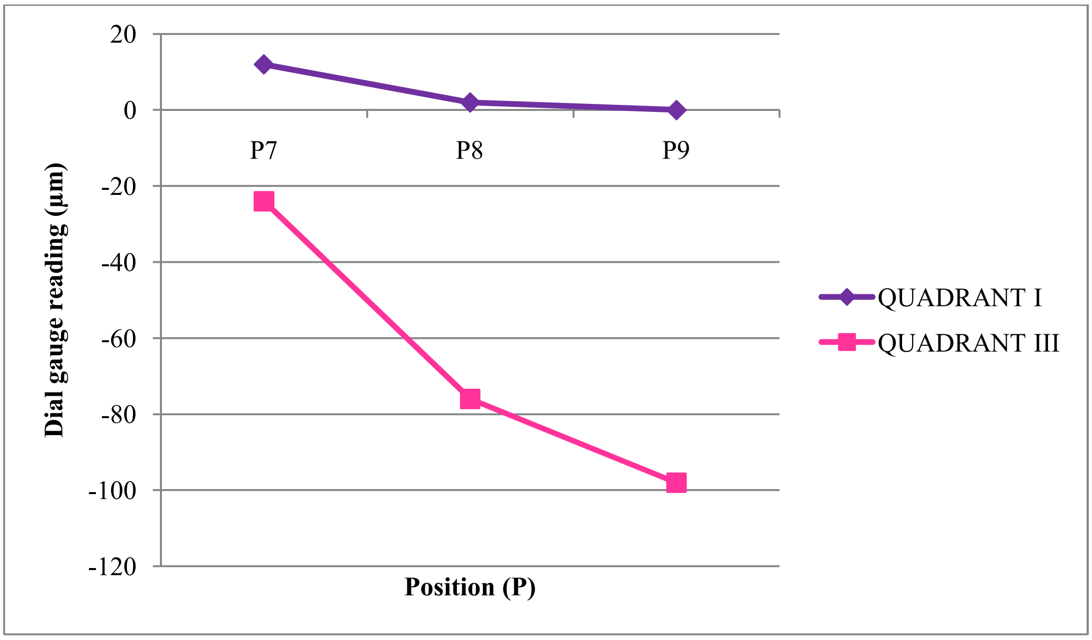



**Figure 4.5:** Graph of dial gauge reading vs. position 7, 8 and 9 for quadrant I and III for workpiece no. 1

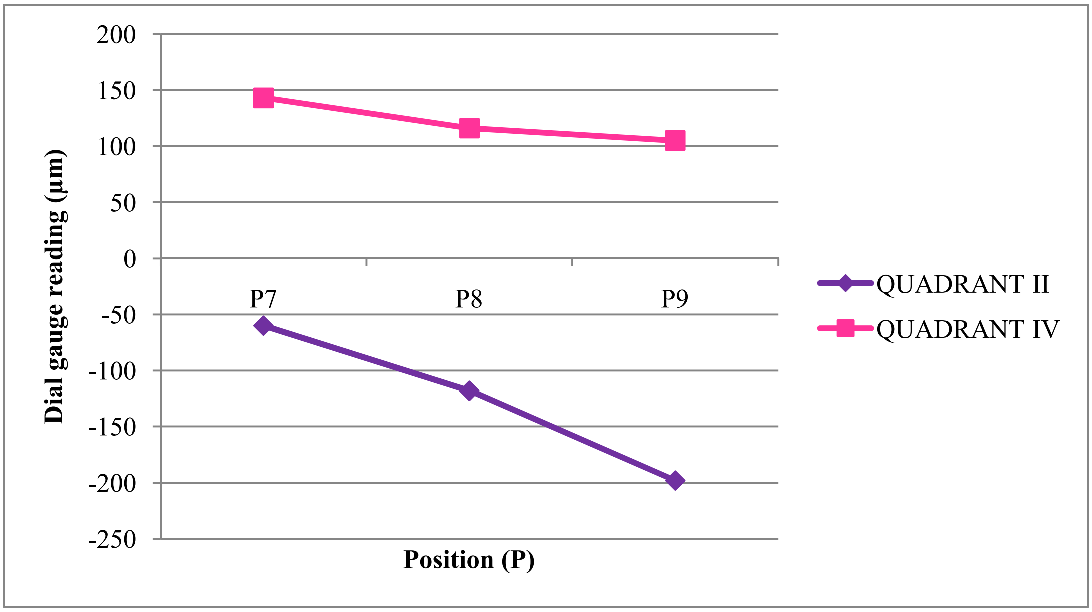



**Figure 4.6:** Graph of dial gauge reading vs. position 7, 8 and 9 for quadrant II and IV for workpiece no. 1

### 4.3.2 Analysis of Workpiece No. 2

For the second workpiece, the following parameters are used:

i) Spindle speed = 600 rev/min
ii) Feed rate = 0.15, 0.45, 0.75 mm/rev
iii) Depth of cut = 1.5 mm

Figure 4.7 until Figure 4.12 are representing the dial gauge reading for the second workpiece. Based on Figure 4.7, point 1 that is located in quadrant III and point 2 that is in quadrant I are categorized as an extreme points. Both points are found at the first step of the workpiece. In this particular step, the spindle speed is set to 600 rev/min, the feed rate is 0.75 mm/rev and the depth of cut is fixed as 1.5 mm. The extreme points are observed because the highest value of feed rate was used and it gives strong effect to the workpiece geometry. As the result, the geometry deviates from the cylindrical shape. Figure 4.8 shows the common trend as most of the other graphs attained in this experiment. The geometry does not deviate too much as the points possess in the Figure 4.7.

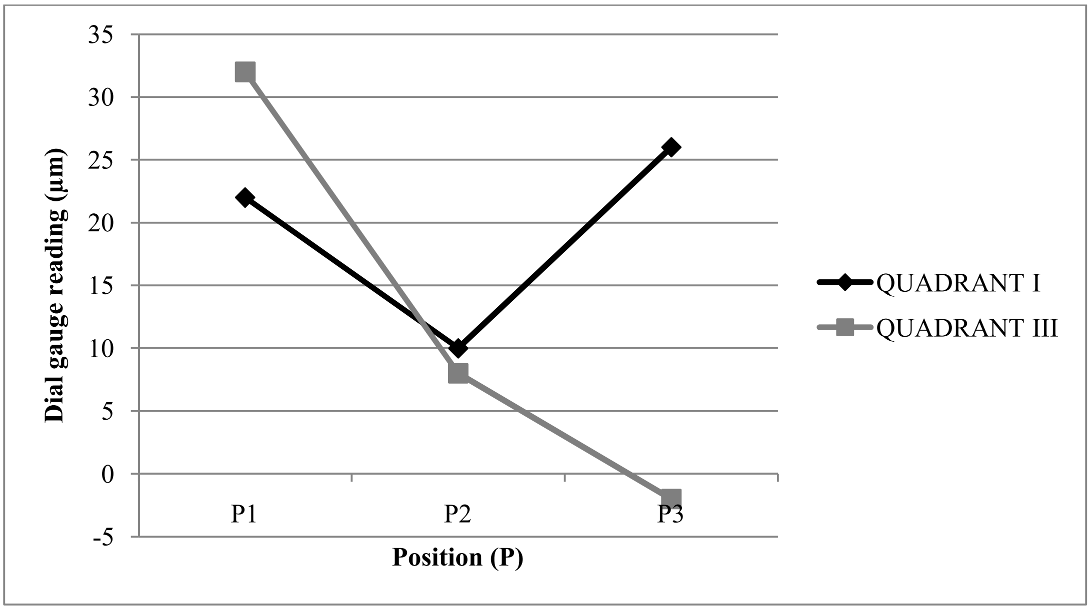



**Figure 4.7:** Graph of dial gauge reading vs. position 1, 2 and 3 for quadrant I and III for workpiece no. 2

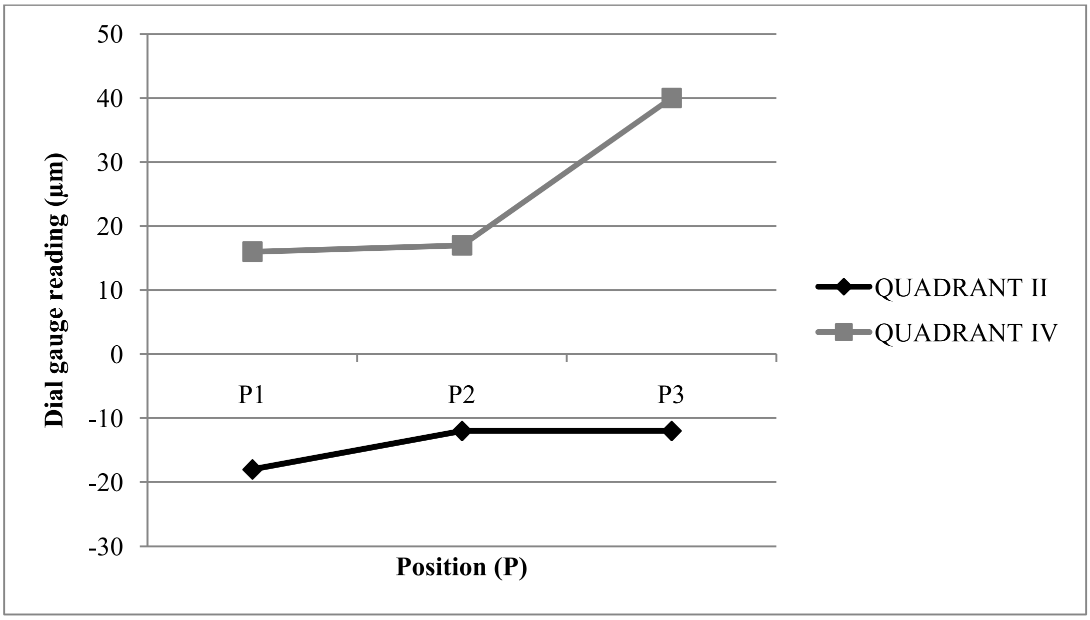



**Figure 4.8:** Graph of dial gauge reading vs. position 1, 2 and 3 for quadrant II and IV for workpiece no. 2

Figure 4.9 and 4.10 are the emerged at the middle step of the second workpiece. The trend of these graphs is the most hideous among all. There are some possibilities that cause this to happen. The surface quality is observed to be obviously threaded and this parallel to the greater value of surface roughness. This surface may be result from the improper alignment of spindle and screw thread in the lathe machine.

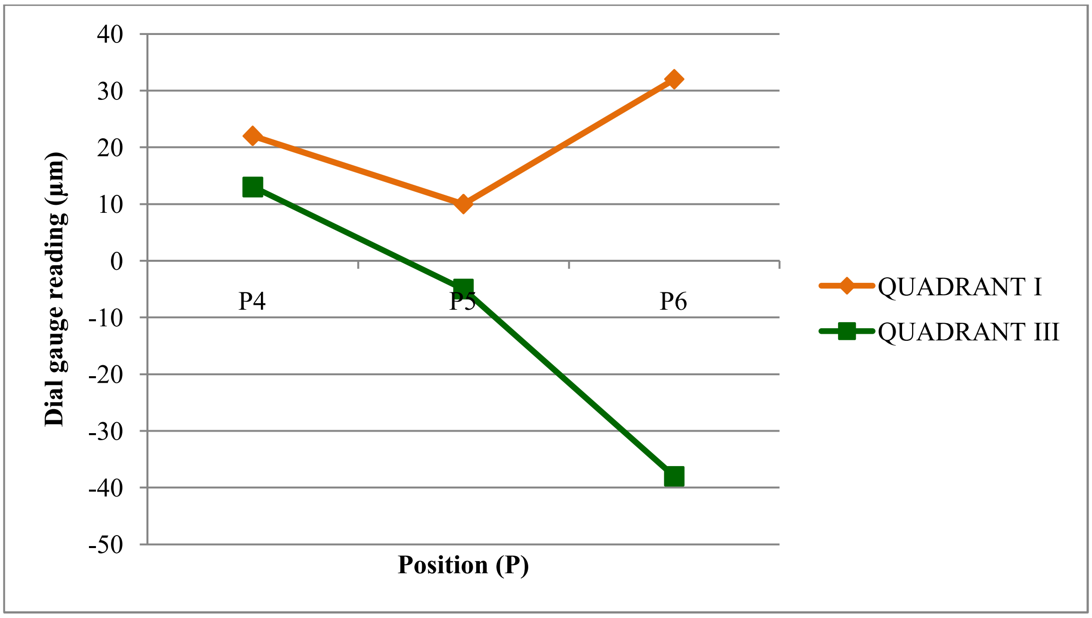



**Figure 4.9:** Graph of dial gauge reading vs. position 4, 5 and 6 for quadrant I and III for workpiece no. 2

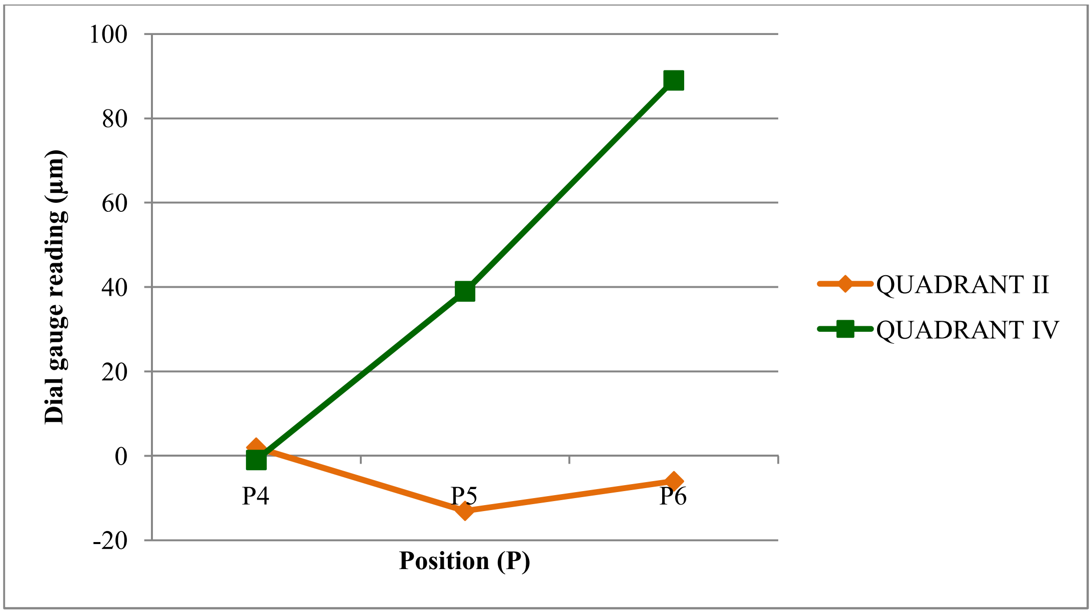



**Figure 4.10:** Graph of dial gauge reading vs. position 4, 5 and 6 for quadrant II and IV for workpiece no. 2

By referring to Figure 4.11, point 8 in quadrant I and III shows the biggest difference among other points, point 7 and 9. The difference may caused when the probe of the dial gauge pass by the contaminate surface which can be specified as corrosion. This problem occurred because one of the properties of mild steel is poor to corrosion resistance.

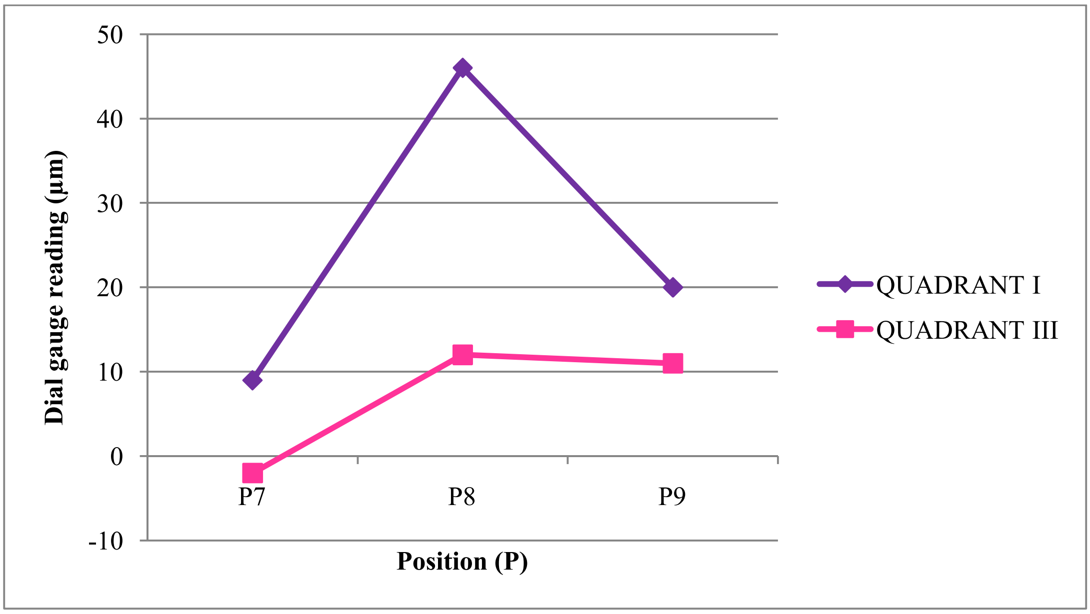



**Figure 4.11:** Graph of dial gauge reading vs. position 7, 8 and 9 for quadrant I and III for workpiece no. 2

Figure 4.12 exhibits the deviate trend from point 7 to point 9. The difference is increasing from 8 point to 36 point and finally to 50 point. Comprehensively, feed rate had the biggest effect on surface roughness. Smallest value of surface roughness was produced when the workpiece was machined with smallest feed rate. It can be conclude that the surface roughness is directly proportional to feed rate. This clearly explains that better surface is obtained at lower feed rates.

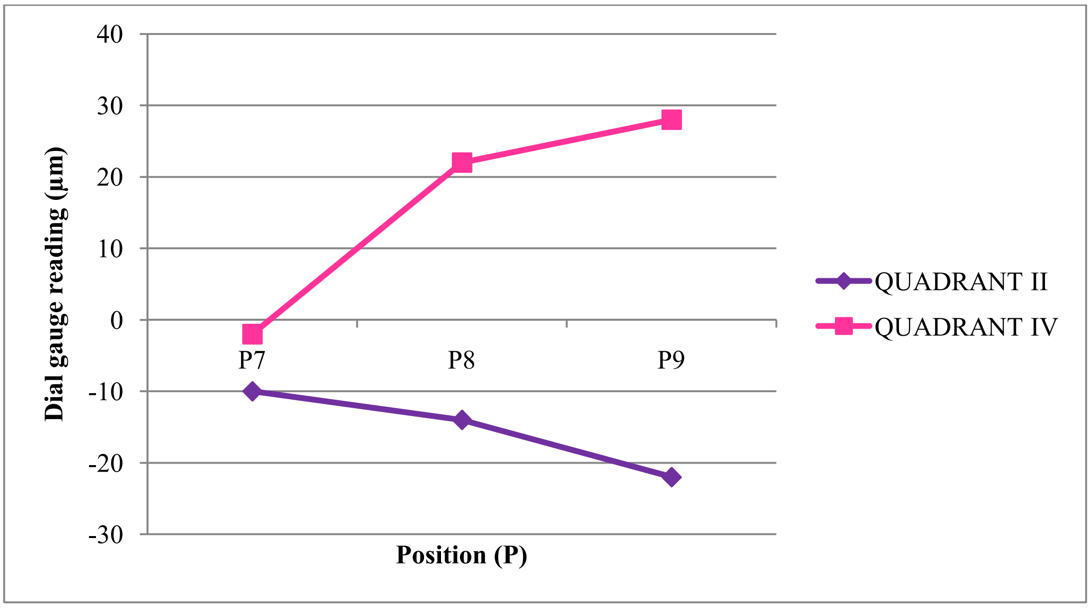



**Figure 4.12:** Graph of dial gauge reading vs. position 7, 8 and 9 for quadrant II and IV for workpiece no. 2

### 4.3.3 Analysis of Workpiece No. 3

For the third workpiece, the following parameters are used:

i) Spindle speed = 600, 900, 1200 rev/min
ii) Feed rate = 0.15 mm/rev
iii) Depth of cut = 1.5 mm

From the reading obtained from the dial gauge, the measurement of cylindricity can be observed by generating the graphs. Figure 4.13 until Figure 4.18 are the graphs for the third workpiece.

The trend of five graphs, Figure 4.13 until Figure 4.15, Figure 4.17 and Figure 4.18 as shown above is almost similar. However, for graph shown in Figure 4.16, the lines of quadrant II and IV are overlapped. This workpiece has undergone the different level of spindle speed, which is rising from one point to another. Poor clamping arrangement may influence on the measurements. This can cause the shape of the workpiece to deform, further on the dial gauge to point out the severest reading.

Although the cutting speed had a moderate effect on cylindricity, it should be taken into consideration because increasing cutting speed leads to reduce cutting forces. Cutting force has a significant effect on the geometrical errors of turned workpiece; higher radial cutting force results in larger geometrical errors.

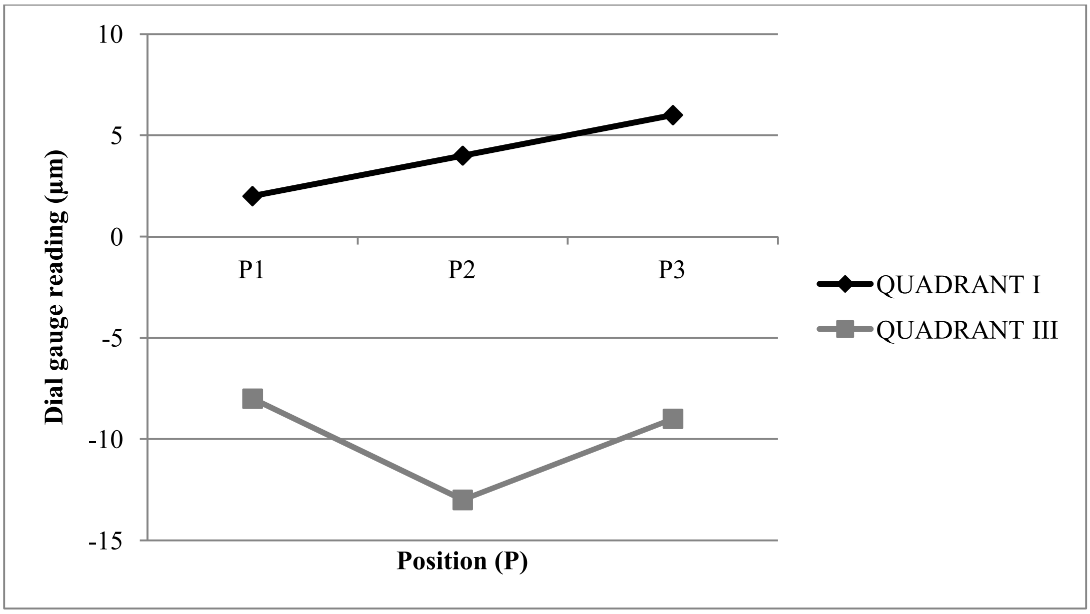



**Figure 4.13:** Graph of dial gauge reading vs. position 1, 2 and 3 for quadrant I and III for workpiece no. 3

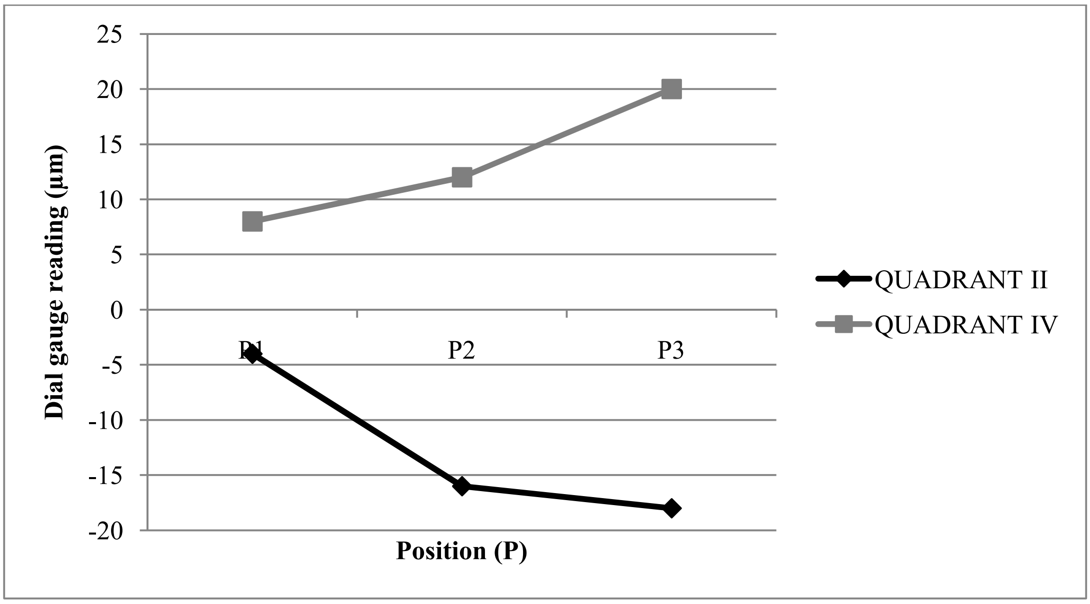



**Figure 4.14:** Graph of dial gauge reading vs. position 1, 2 and 3 for quadrant II and IV for workpiece no. 3

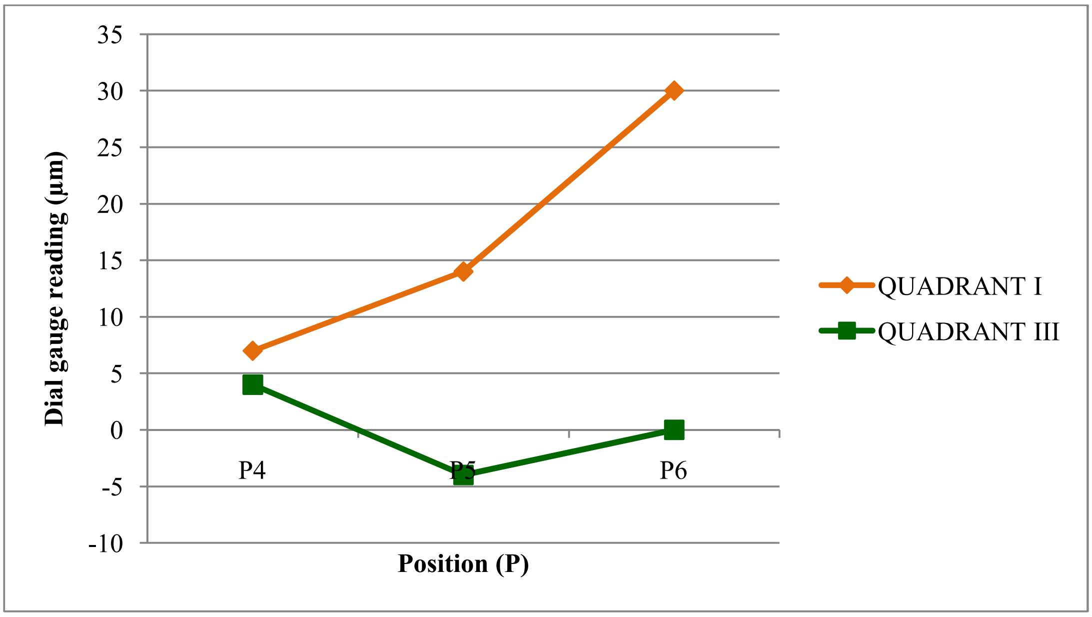



**Figure 4.15:** Graph of dial gauge reading vs. position 4, 5 and 6 for quadrant I and III for workpiece no. 3

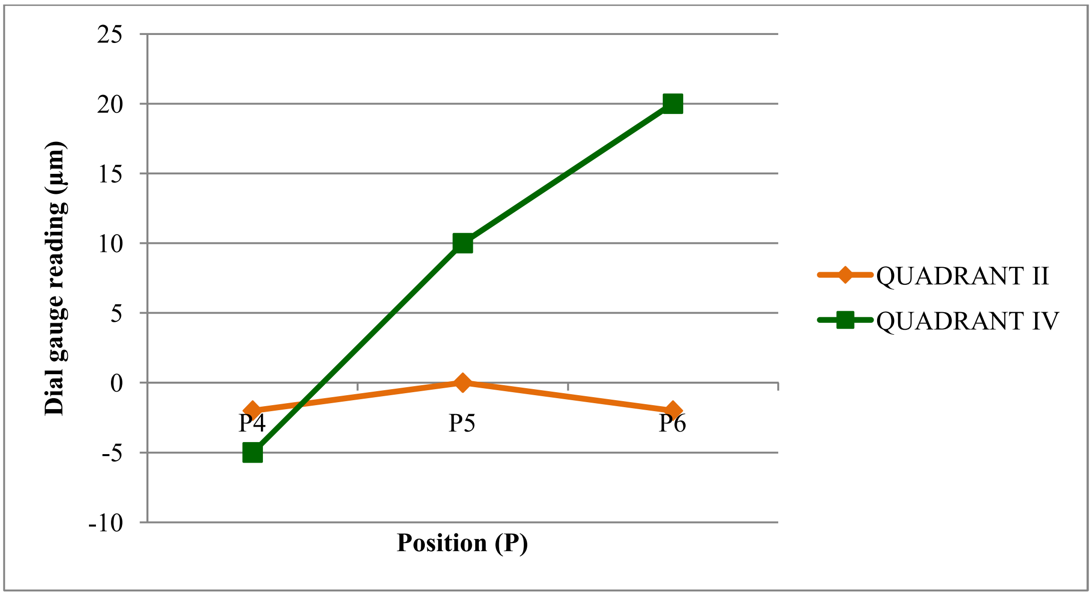



**Figure 4.16:** Graph of dial gauge reading vs. position 4, 5 and 6 for quadrant II and IV for workpiece no. 3

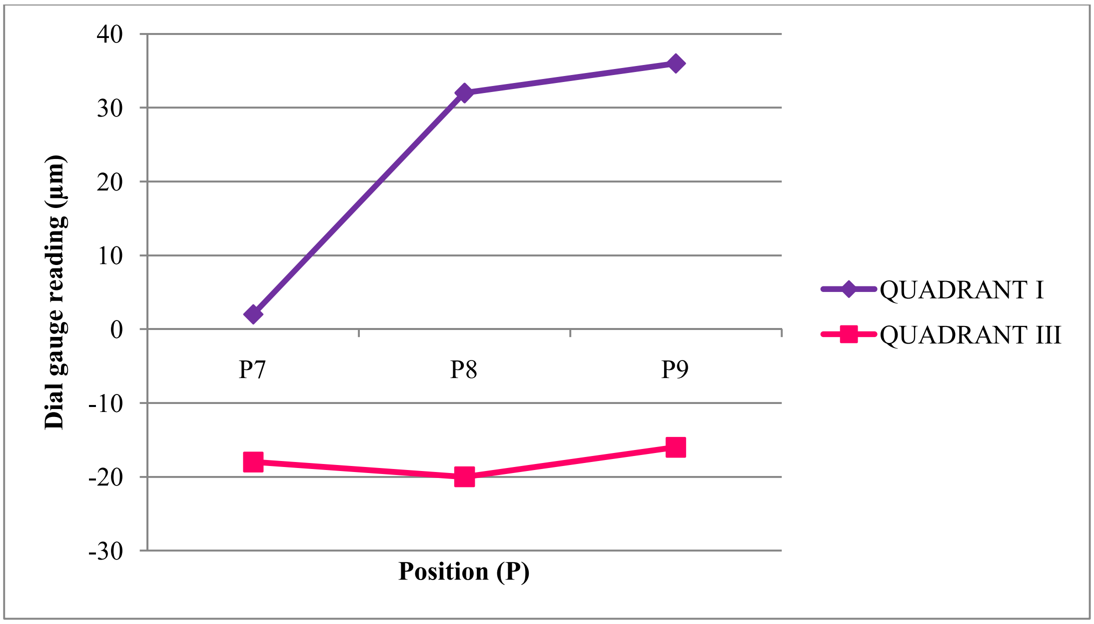



**Figure 4.17:** Graph of dial gauge reading vs. position 7, 8 and 9 for quadrant I and III for workpiece no. 3

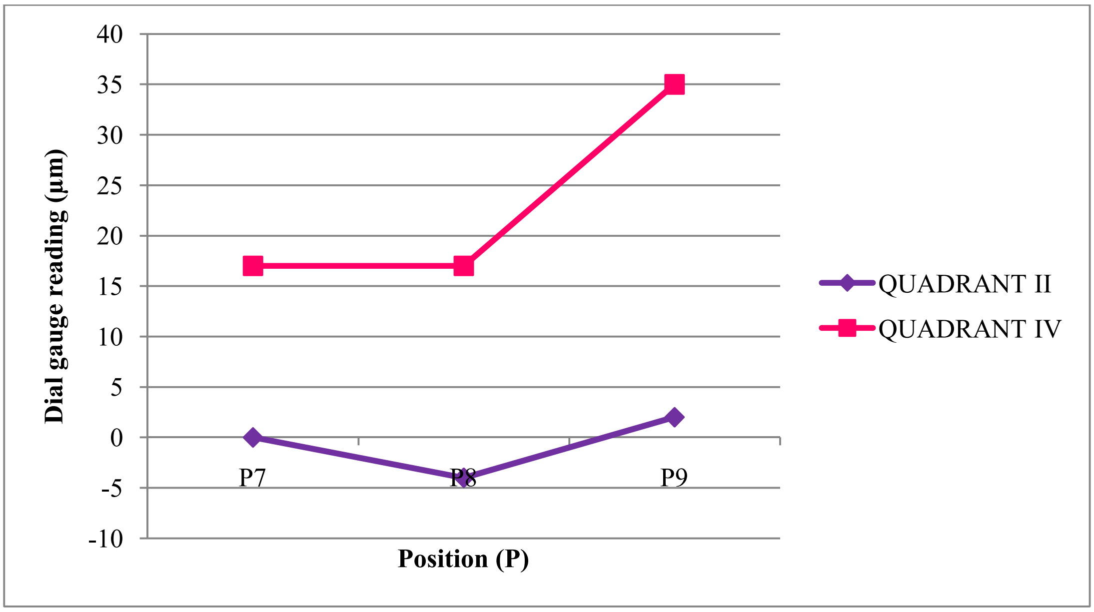



**Figure 4.18:** Graph of dial gauge reading vs. position 7, 8 and 9 for quadrant II and IV for workpiece no. 3

## 4.4 SUMMARY

From the above analysis and by referring to the graphs, the best combinations of parameters that have been detected are:

i) Depth of cut = 0.5 mm

ii) Feed rate = 0.15 mm/rev

iii) Cutting speed = 150 m/min

Cylindricity effect is strongly related to the surface roughness due to its capability to influence the geometrical shape of the workpiece because surface roughness may affects the functional characteristic of the workpiece such as fatigue resistance, friction and wearing. Decreasing in surface roughness will increase the surface quality.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 INTRODUCTION

Chapter 5 summarizes all the main research points of this dissertation. It concludes that all the important information and observation resulting from the project for the future research.

## 5.2 CONCLUSION

The study on investigating the cylindrical effect based on three different parameteters and levels on the workpiece of medium carbon steel in conventional lathe machine was performed. From the analysis that has been made, feed rate was considered as important parameters for the cylindricity measurement since it has the biggest effect on the surface roughness. As for the cutting speed, it gives a moderate effect and it also related to the cutting force during the machining process. It is because increasing in cutting speed leads to reduce the cutting forces and this will help to exhibit better surface along with good cylindrical model. For depth of cut, it shows an insignificant effect to the cylindricity measurement unless by fusing it with higher cutting speed. This combination will prevent the formation of build-up-edge, thereby aiding the process by yielding a better surface finish. The other conditions that may affect the cylindricity of workpiece are the machine condition and also environment factor whereby the machine condition like the vibration of spindle may cause its amplitude and frequency to give strong effect on the surface topography. Furthermore, the environment factor that obviously seen was the corrosion. The layer of rust on the workpiece surface may affect during the measurement or geometry evaluation process. This conclusion is also proven according to the literature that had already been made.

## 5.3 RECOMMENDATION

There are some recommendations to be considered in improving the details of this project. In machining process especially in turning, the best combination cutting parameters should be studied and chosen before experiment begins since this is essential to maximize the surface smoothness which leads to earn better cylindrical geometry. As for the material, special attention should be focused on the material properties. If the material occupies poor corrosion resistance, proper anti-corrosive agent should be applied such as grease and oil to avoid the present and appearance of rust on the surface of the workpiece. The experiments also can be conducted using CNC lathe machine as it possesses better rigidity compared to conventional lathe machine. Besides that, regular maintenance is required for any type of machine because this is to ensure the spindle is clean from dirt and dry from moisture. Contaminated parts can lead to failure. Moreover, the alignment of the spindle should be checked before starting the experiment because the shift of spindle may probably occur due to different distribution of forces acting on the tool during turning operation. Other than that, a better cylindricity measurement is highly recommended to be evaluated using coordinate measuring machine because the accuracy factor. Surface roughness should be taken into consideration as well in evaluating cylindricity because roughness plays a significant role in determining and evaluating the surface quality of a product. So, after the turning operation, surface roughness measurement should be done as well as the cylindricity measurement to clearly see the relationship between these two measures.

# REFERENCES


Adamczak, S., Janecki, D., and Stepien, K. (2003). Concept of Reference Measurements of Cylindricity Profiles of Machine Parts. 1764-1768.

Adamczak, S., Janecki, D., and Stepien, K. (2006). The Comparison of Cylindricity Profile using Normalized Cross correlation Function. 18-21.

Al-Wedyan, H., Demirli, K., and Bhat, R. (2004). Fuzzy Modeling and Prediction of Cylindricity Error in BTA Deep Hole Boring Process. 979-984.

Bruce R. G., Dalton W. K., Neely J. E., and Kibbe R. R. (2004). *Modern Materials and Manufacturing Processes.* Third Edition. Ohio: Pearson-Prentice Hall.

Beauchamp Y., Thomas M., Youssef Y. A., and Masounave J. (1996). *Investigation of Cutting Parameter Effects on Surface Roughness in Lathe Boring Operation by Use of a Full Factorial Design.* China: China Machine Press.

Chajda, P. D., Grzelka, D. E., Gapinski, M. E., Pawlowski, M. E., Szelewski, M. E., & Rucki, D. E. (2008). Coordinate Measuremen of Complicated Parameters like Roundness, Cylindricity, Gear Teeth or Free-form Surface. *Kranevo* , 225-231.

Dudzinski, D., Molinari, A., & Schulz, H. (2002). *Metal Cutting and High Speed Machining.* New York: Kluwer Academic.

Groover, M. P. (2007). *Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Third Edition.* United States of America: John Wiley & Sons, Inc.

Hadi, Y. & Ahmed S. G. (2006). *Assessment of Surface Roughness Model for Turning Process,* International Federation for Information Procesing.

Herreraa, C., Limab, N. B., Filhoc, A. F., & Plautd, R. (2006). Texture and Mechanical Properties Evolution of a Deep Drawing Carbon Steel During Cold Rolling and Subsequent Recrystallization. 7.

Huff, S. (2009). What is Your Roller's True Shape and Why Does It Matter? 1-5.

Kirby E. D. (2006). A Parameter Design Study in a Turning Operation Using the Taguchi Method. *Technology Interface*.

Krar, S. F., Gill, A. R., & Smid, P. (2005). *Technology of Machine Tools.* New York: McGraw-Hill.

Kundrak, J., Karpuschewski, B., Gyani, K., & Bana, V. (2007). Accuracy of Hard Turning. *Elsevier* , 328-338.

Lao, Y. Z., Leong, H. W., Preparata, F. P., & Singh, G. (2003). Accurate Cylindricity Evaluation with Axis-Estimation Preprocessing. *Elsevier* , 429-437.

Nelson, D. H., & George Schneider, J. (2001). *Applied Manufacturing Process Planning: With Emphasis on Metal Forming and Machining.* New Jersey: Prentice Hall.

Serope Kalpakjian, S. R. (2007). *Manufacturing Engineering and Technology, Fifth Edition in SI Units.* South Asia: Prentice Hall Pearson Education.

Shuo-Yan Chou, C.-W. S. (2000). Assessing Cylindricity for Oblique Cylindrical Features. *Pergamon International Journal of Machine Tools & Manufacture*, 327-341.

Thamma R. Comparison between Multiple Regression Models to Study Effect of Turning Parameters on the Surface Roughness. *Central*.

Whitehouse, D. J. (1994). *Handbook of Surface Metrology.* United Kingdom: CRC Press.

Wiliam F Smith, J. H. (2006). *Foundations of Materials Science and Engineering, Forth Edition.* Singapore: Mc-Graw Hill.

**APPENDIX A - GANTT CHART FOR FYP 1**

| BIL | PROJECT ACTIVITIES | WEEK | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **1** | **PREAMBLE** | | | | | | | | | | | | | | | | |
| i | Verification of project title | | | | | | | | | | | | | | | | |
| ii | Briefing by FYP coordinator | | | | | | | | | | | | | | | | |
| iii | Literature study | | | | | | | | | | | | | | | | |
| **2** | **WRITING REPORT** | | | | | | | | | | | | | | | | |
| i | Chapter 1 - Overview | | | | | | | | | | | | | | | | |
| | * Project title | | | | | | | | | | | | | | | | |
| | * Objectives | | | | | | | | | | | | | | | | |
| | * Scopes of study | | | | | | | | | | | | | | | | |
| | * Project background | | | | | | | | | | | | | | | | |
| ii | Chapter 2 - Literature Review | | | | | | | | | | | | | | | | |
| | * Steel | | | | | | | | | | | | | | | | |
| | * Cutting tool | | | | | | | | | | | | | | | | |
| | * Lathe machine | | | | | | | | | | | | | | | | |
| | * Coordinate measuring machine | | | | | | | | | | | | | | | | |
| iii | Chapter 3 - Methodology | | | | | | | | | | | | | | | | |
| | * Process flow chart | | | | | | | | | | | | | | | | |
| | * Material selection | | | | | | | | | | | | | | | | |
| | * Determining machines/ equipments | | | | | | | | | | | | | | | | |
| | * Design of experiment | | | | | | | | | | | | | | | | |
| | * Confirm material and machines | | | | | | | | | | | | | | | | |
| **3** | **RESOLUTION** | | | | | | | | | | | | | | | | |
| i | Submit draft of Chapter 1, 2 and 3 | | | | | | | | | | | | | | | | |
| ii | Make necessary correction | | | | | | | | | | | | | | | | |
| iii | Presentation of FYP 1 | | | | | | | | | | | | | | | | |
| iv | Submit full report of FYP 1 | | | | | | | | | | | | | | | | |

100% done

50%done

not done yet

## APPENDIX B - GANTT CHART FOR FYP 2

| BIL | PROJECT ACTIVITIES | WEEK | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **1** | **PREAMBLE** | | | | | | | | | | | | | | | | |
| i | Purchase material | | | | | | | | | | | | | | | | |
| ii | Seek approval to run machines | | | | | | | | | | | | | | | | |
| iii | Run experiment | | | | | | | | | | | | | | | | |
| iv | Analyze data | | | | | | | | | | | | | | | | |
| v | Confirmation run | | | | | | | | | | | | | | | | |
| **2** | **WRITING REPORT** | | | | | | | | | | | | | | | | |
| i | Chapter 4 - Result and Discussion | | | | | | | | | | | | | | | | |
| | * Collect data | | | | | | | | | | | | | | | | |
| | * Interpret data | | | | | | | | | | | | | | | | |
| | * Discussion | | | | | | | | | | | | | | | | |
| ii | Chapter 5 - Overall Conclusion | | | | | | | | | | | | | | | | |
| | * Making summary of the project | | | | | | | | | | | | | | | | |
| | * State recommendation | | | | | | | | | | | | | | | | |
| **3** | **RESOLUTION** | | | | | | | | | | | | | | | | |
| i | Submit draft of Full Thesis | | | | | | | | | | | | | | | | |
| ii | Make necessary correction | | | | | | | | | | | | | | | | |
| iii | Presentation of FYP 2 | | | | | | | | | | | | | | | | |
| iv | Submit full report of FYP 2 | | | | | | | | | | | | | | | | |

100% done

50%done

not done yet