Study into the Effect of Crude Palm Oil (CPO) as a Cutting Fluid on the Surface Finish and Roundness During Lathe Cutting Operation.

by

Rubiah Binti Ab Ghani

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

DECEMBER 2010

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CERTIFICATION OF APPROVAL

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Approved by,

____
(AP Dr Mustafar bin Sudin)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own expect as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

RUBIAH BINTI AB GHANI

ABSTRACT

Cutting fluids are widely used in machining either as a lubricant or coolant. In supporting green machining concept that concern on environmental effect and health problem, vegetable oils are finding their way as lubricant for industrial and transportations applications.The first two objectives of this project are to be able to study the effect of crude palm oil (CPO) on the surface roughness and roundness of stainless steel workpiece. CPO is used as cutting fluid during turning operation. The turning operation also involve the dry cutting and turning with Solkut. After turning, the roughness and roundness of workpiece are measured using Mahr Perthometer Concept-Surface Profiler and Mitutoyo Round-Test Machine respectively. The third objective is to comparing the roughness and roundness result between dry cutting, Solkut and CPO.The results of surface roughness are presented in two ways which are Mean Surface Roughness, Ra and Mean Roughness Depth, Rz. Same as roundness, measurement is repeated for three times and average of roundness is calculated. All the results are presented in data tables and graphs are plotted to compare the performance between CPO with Solkut and dry cutting. From the results achieved in this project, it illustrates some of the positive and encouraging performance. But somehow, the results shown by CPO are insufficient to be support as a cutting flood. However, in the future, the author believes that this project would be a success if proper improvements are taken to CPO. Their performances in those operations were promising enough to encourage further development.

ACKNOWLEDGEMENT

Assalamualaikum w.b.t and Alhamdulillah,

First and foremost, I would like to praise and thank to the Lord above for giving me guidance, assistance and strength in completing this Final Year Project successfully on the time and making it a success. Without His assistance, I would not be able to finish and complete this project.

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I also want to express my gratitude to all the technicians and the staffs involved in this project, especially Mr Jani, Mr Shaiful, Mr Zamil, Mr Adam and Mr Faisal, either directly or indirectly. Their assistance was really appreciated and treasured, for without their help, sure I would have faced many difficulties in using the machines and equipments that I was not used to. They have not jut helped in the accomplishment of this project, but also have been giving a good support and helping hand through out the period.

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Rubiah Binti Ab Ghani

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CHAPTER 1
INTRODUCTION

1.1 PROJECT BACKGROUND

In lathe or turning operation, material is removed from the external surface of a cylinder rotating workpiece. The performance of a turning operation is greatly influenced by the application of cutting fluid. Without cutting fluid, heat is generated and can affect the quality of the machined workpiece. The main sources of heat in machining are: (a) the work done in shearing in the primary shear zone, (b) energy dissipated as friction at the tool-chip interface, (c) heat generated as tool rubs against the machined surface especially for dull or worn tools [2]. The heat generated during the lathe can have an effect on other properties too such as on the cutting forces, tool life, surface toughness, dimensional accuracy and tolerances.

Cutting fluids act as coolant, or lubricant, or both and they are important in reducing the severity of the contact processes at the cutting tool-workpiece interfaces. Historically, more than 100 years ago, water was used mainly as a coolant due to its high thermal capacity and availability. Corrosion parts and machines and poor lubrication were the drawbacks of such a coolant. Oils were also used in this time as these have much higher lubricity, but the lower cooling ability and high cost restricted this use to low cutting speed machining operations [1, 2].

In addition, cutting fluid may reduce the cutting force such as friction, therefore heat generation is reduced to some extent. Using the cutting fluid, the heat generated in machining can be rapidly removed away by convection.

Malaysia currently accounts for 41 % of world palm oil production and 47% of world exports, and therefore also for 11% and 25% of the world's total production and exports of oils and fats [13]. Due to the abundant of crude palm oil (CPO), the research is conducted to explore the potential of CPO as a cutting fluid in machining process such as turning. In addition, green machining becomes more popular due to safety of the environment and human health concern [12]. CPO is a biodegradable oils and can be used as alternative cutting fluid in supporting green machining. CPO can be known as vegetable oils that contain triglycerides ester molecules [3]. The triglyceride structure of vegetable oils provides qualities desirable in a lubricant. Long, polar fatty acid chains provide high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear [14].

Turning is greatly influenced by independent input variables which are cutting speed, feed rate and depth of cut. These parameters are commonly known as cutting conditions. These cutting conditions are also believed to have significant effects on the quality of machined parts. The quality of turned parts is specified by a number of quality characteristics: diameter error, circularity (roundness) and surface roughness [6]. However in this project, only roundness and surface roughness are selected for monitoring the quality of turned parts.

1.2 PROBLEM STATEMENT

- Cutting fluid is a solution used during a machining process purposely to reduce cutting temperature, produce better surface finish and improve dimensional accuracy of machined workpiece and also acts as coolant agent. However a commercial mineral base cutting fluid is difficult to treat compare to biodegradable CPO. Therefore using CPO might suggest the alternative.

- Besides using the commercial cutting fluid which is mineral soluble oils and assumed to be expensive, crude palm oil also possible to be used as cutting fluid during turning and could improve surface roundness and give better finish to the surface of workpiece and it is assumed cheaper than the commercial cutting fluid.

1.3 OBJECTIVES

The main objectives of this project are listed as followed:

1. To study the quality of surface finish when using crude palm oil as cutting fluid in lathe machining.
2. To study the behavior of roundness when using crude palm oil as cutting fluid in lathe machining.
3. To compare the result of surface finish and roundness between crude palm oil and other commercial cutting fluid.

1.4 SCOPE OF STUDY

To complete the project in the time given, the author need to focus her scope of work into several items;

- Do research on the potential of CPO as cutting fluid.
- Study on the lathe or turning machining parameters.
- Understanding the terminology of surface finish and roundness in lathe machining.
- Experiment the effect of CPO to the surface finish and roundness.
- Determine the standard of lathe machining process.

For this time being, there are only two parameters are taken into consideration as the dependent variables which are surface roughness and roundness. The controlled or independent variables in the study are feed rate. The cutting speed and depth of cut are kept constant. The workpiece material will be austenitic stainless steel and cutting tool is made from titanium nitride (TiN) coated carbide.

CHAPTER 2
LITERATURE REVIEW

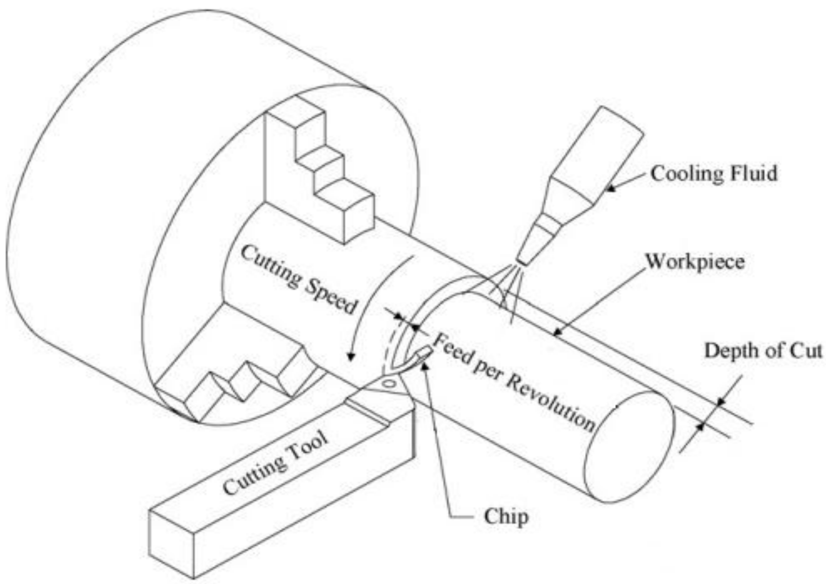


Figure 2.1: Scheme of turning operation [17]

In the turning operation, few quality characteristics will be considered to determine the quality of turned workpiece. They are surface roughness and roundness or circularity.

2.1 SURFACE FINISH MEASUREMENT

Surface finish or also known as surface roughness is a measure of the fine irregularities on a surface and is defined by the height, width, direction and shape of irregularities [15]. The surface finish of machined workpiece is an important aspect in metalworking lubrication. Surface finish may be measured or indicated in terms of roughness, waviness, lay and form as shown in Figure 2.2 [5] and Figure 2.3. The surface roughness profiles can be obtained from surface profiler machine.

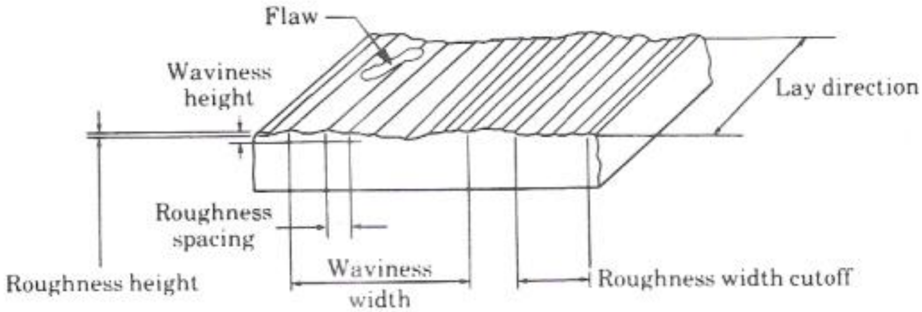


Figure 2.2: Surface finish terminology and symbols [5].

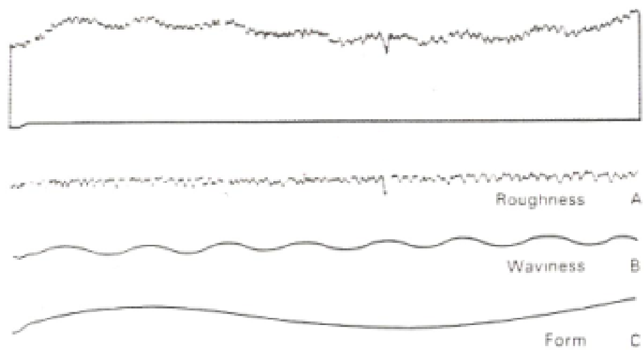


Figure 2.3: A surface profile represents the combined effects of roughness, waviness and form [21]

a) Roughness – the irregularities which are inherent in the production process.
b) Waviness – component of the texture upon which roughness is superimposed. It may result from such factors as vibrations, chatter or work deflection.
c) Form – general shape of the surface.
d) Lay – directional characteristic of machining patterns on many surfaces.[21]

Mahr: Pethometer PGK 120 is one of available surface profiler that will be used during the experiment. This equipment is a modular computer controlled station for measuring and analysis of roughness and contour and it uses stylus method to measure the surface roughness.

Lin, Lee and Wu (199) [11] had constructed a prediction model for surface roughness and cutting force. The surface roughness value increased with the increasing of feed rate. It can be seen clearly that the surface roughness increases with the increased depth of cut but the impact of changes in the cutting speed on the surface roughness is less significant.

There are several roughness parameters that need to be consider in measuring the surface of workpiece based on the standard by DIN EN ISO 4287, ASME B46.1[22]. The parameters are as followed;

a) ***Ra*** (mean surface roughness) – arithmetic average of the absolute values of the roughness profile ordinates.

$$R_a = \frac{1}{l}\int_0^l |Z(x)|\, dx \qquad (2.1)$$

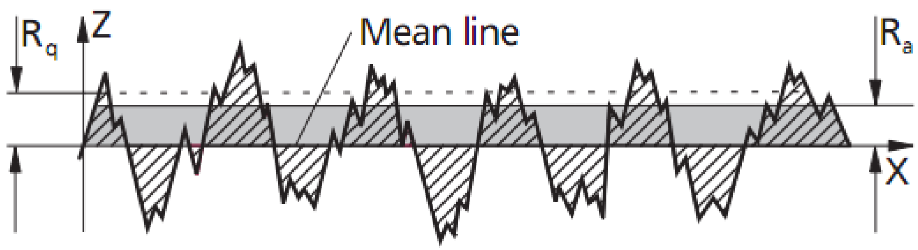


Figure 2.4: Arithmetic average roughness value [22]

b) ***Rz***

c) ***Rz*** (mean roughness depth) – arithmetic mean value of the single roughness depth, Rz_i of consecutive sampling length.

$$R_z = \frac{1}{n}(R_{z1} + R_{z2} + \ldots + R_{zn}) \qquad (2.2)$$

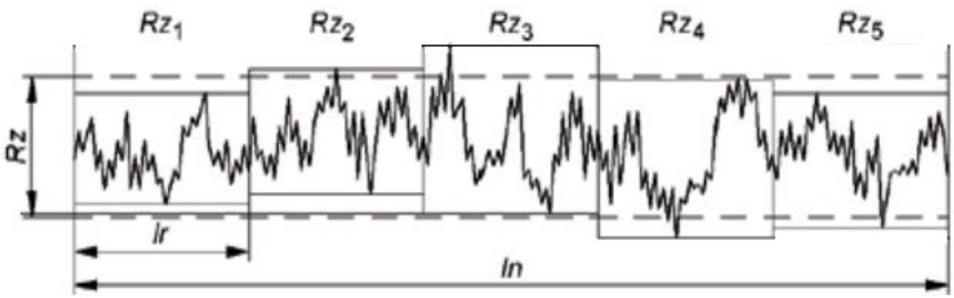


Figure 2.5: Roughness depth [22]

2.2 ROUNDNESS MEASUREMENT

For turned parts, surface roundness is another important quality characteristic that is geometric in nature. It is defined by two concentric circular of boundaries within which each circular element of the surface must lie [15].

As turning insert has an orthogonal orientation to the axis of rotation of workpiece, the tool nose radius can create radial force that affecting the turned surface. The radial force has little effect on the 'harmonic' of the surface roundness when close to the tailstock. Once the cutting insert has progressed some distance along the workpiece, the influence of tailstock is lessened and increases the effect of the radial force. Thus the harmonic departures from roundness are significant [18].

2.2.1 Least Square Circle Method

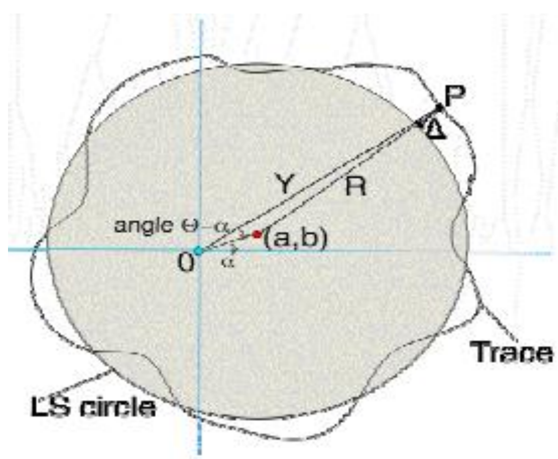


Figure 2.6: Least Square Circle Method [24]

Least square circle (LSC) is the method use by round-test machine to calculate the roundness. The least square fit of points on the trace to circle define the parameters of non-circularity of the work piece. From the diagram above:

Y = the distance from the spindle center to the trace at an angle θ

R = Radius of the circle

P = Distance from the center of the circle to the trace.

A LSC fit to the data gives the following estimate for the parameters:

$$\bar{R} = 1/N\ (\sum Yi.) \qquad (2.3)$$

$$\bar{a} = 2/N\ (\sum Y\ i.^{*} \cos \theta i.) \qquad (2.4)$$

$$\bar{b} = 2/N\ (\sum Yi.\ \mathrm{Sin}\ \theta i.) \qquad (2.5)$$

The deviation of the trace from the circle at angle θi., which define the non-circularity of the work piece, is estimated by;

$$\bar{\Delta} = Yi. - \bar{R} - \bar{a} \cos \theta i. - \bar{b} \sin \theta i. \qquad (2.6)$$

Before analysis of the result is performed, some important terminologies in the roundness are needed to be understood first.

The terminologies in the analysis are:

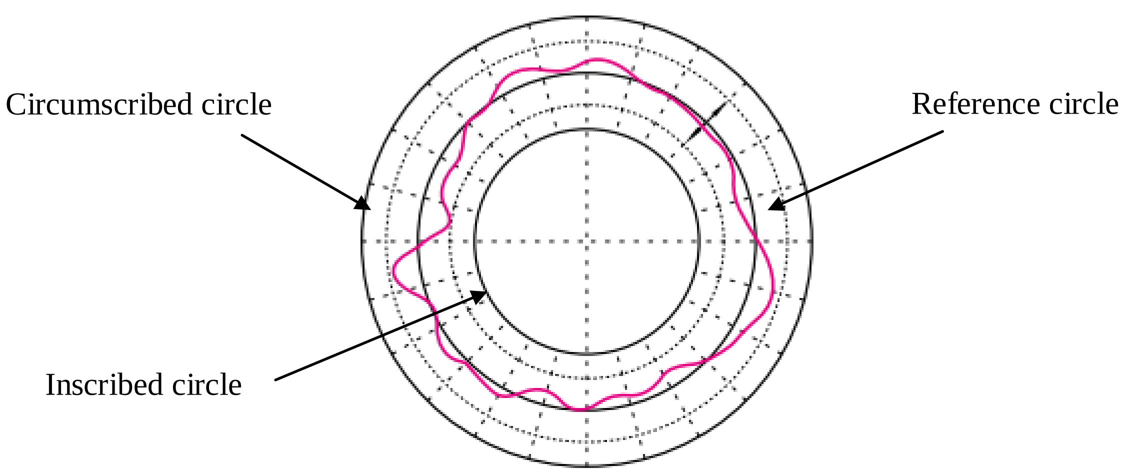
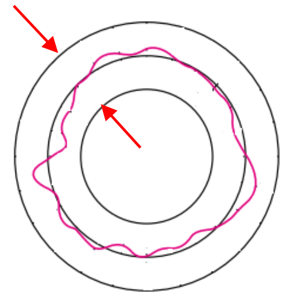
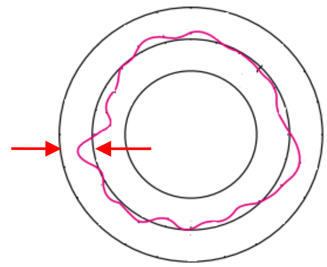
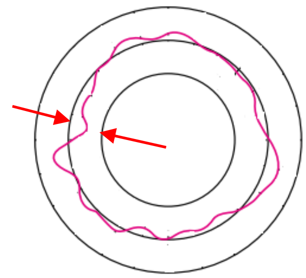
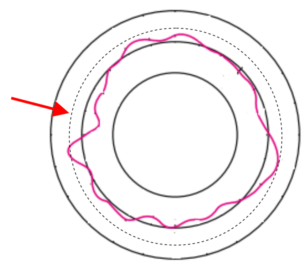
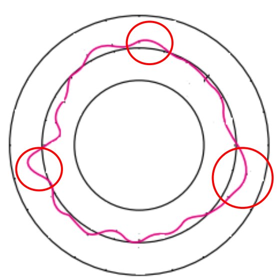


Figure 2.7: 3 basic circles in roundness analysis

Table 2-1: Description of analysis term

Description	Figure
• Roundness - Roundness is determined from the difference between the radii of the inscribed circle and circumscribed circle, both of which are concentric to the center obtained by each evaluation method.	
• Peak height, P - Peak height is determined from the difference between the radii of the reference circle and the concentric circumscribed circle	
• Valley depth ,V - Valley depth is determined from the difference between the radii of the reference circle and concentric inscribed circle.	
• Mean roundness - Mean roundness is determined from the mean of the absolute value of deviations from the reference circle	
• Peak count - Peak count or number of peak is determined from the number of peaks higher than the reference circle. A peak between the point where the data rises above the reference circle and that where the data drops below the reference circle is referred to as one peak.	

2.3 CRUDE PALM OIL

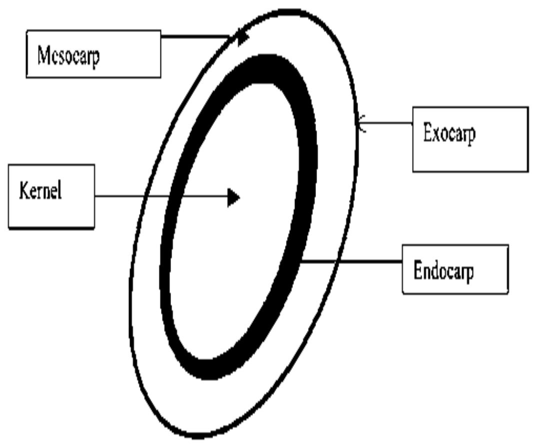


Figure 2.8: Structure of the palm fruit [23]

Figure 2.9: (a) endocarp of palm fruit, (b) mesocarp or fibrous husk of palm fruit. This palm fruit will be process to produce CPO. *Source from FELCRA Nasaruddin*.

Cutting fluid improves tool life by reducing friction, wear and temperature. It also reduces cutting forces and energy consumption and improves surface finish and integrity. Cutting forces and energy requirements are reduced because of friction is reduced, thus requires less energy. Surface finish is improved primarily because of the elimination, reduction or increased stability if the built-up edge, which is significantly, depend on the effectiveness of the cutting fluid [5].

Crude palm oil is a type of boundary lubricant that has higher potential to provide better surface finish and improve roundness of machined workpiece. Boundary films can form rapidly on clean surfaces and if these layer us destroyed, friction and wear will be high.

Maleque, Masjuki and Sapuan (2003) [7] had done a research entitled 'Vegetable-based biodegradable lubricating oil additives'. In this research, they focused on the fatty acid composition of methyl esters of crude palm oil (CPO), crude palm stearin (CPS) and crude palm kernel oil (CPKO). It can be said that fatty acid of palm oil methyl esters (POME) composition can provide effective boundary layer known as boundary lubrication) due to the presence of a polar structure, which dissipates non-polar molecules or base lubricant and can act as an anti-wear additives and friction and friction modifier for the commercial mineral-based lubricating oil.

2.3.1 Properties of Crude Palm Oil

Product name : Crude Palm Oil (CPO)

Physical and chemical properties :

- State : Liquid
- Colour : Reddish
- Flash point : 116.3°C
- Viscosity : 64.69 cSt (at 40°C)
  8.24 cSt (at 100°C)
- Viscosity index: 95
- pH : 4.80

Palm oil is naturally reddish in color because it contains a high amount of beta-carotene. According to the previous research, CPO has higher flash point because of the strong interaction between the molecules. A higher flash point is essential since it can reduce potential fire hazard. In addition, viscosity of CPO varies inversely with temperature as shown above. Viscosity index is referring to the gradient of the viscosity against the temperature. The average of pH value shows CPO is acidic.[9]

2.4 PROPERTIES OF COMMERCIAL CUTTING FLUID

Product name : SOLKUT 2140

Description of product : Proprietary Soluble Metal Working Fluid

Physical and chemical properties:

- State : Liquid
- Colour : Amber
- Odour : Mild
- Oxidizing : Non-oxidizing
- Solubility : Soluble in water and most organic solvents
- Viscosity : Viscous (>40cst)
- Boiling point : >100°c
- Auto flammability : >150°c
- Relative density : 0.95
- pH : 9.3
- Viscosity test method : Kinematic viscosity in 10-6 m^2/s at 40°c [9]

2.5 WORKPIECE MATERIAL

Palm oil has lower pH (pH = 4.80) [9] value compare to commercial cutting fluid, SOLKUT 2140 (pH = 9.30). This shows that palm oil is acidic and lead to corrosion. Thus, it is recommended to use austenitic stainless steel as workpiece compare to low carbon steel since stainless steel has higher corrosion resistance compare to low carbon steel.

Xavior and Adithan (2007) [10] studied the influence of cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel with carbide tool. They attempted to identify the influence of coconut oil in reducing the tool wear and surface roughness during turning process. They compared the performance of coconut oil with another two cutting fluids namely an emulsion and neat cutting oil (immiscible with water). The results indicated that in general, coconut oil performed better than the other two cutting fluids in reducing the tool wear and improving the surface finish. From Figure 2.10 below, it shows that coconut oil always performs better result compare to another two cutting fluids.

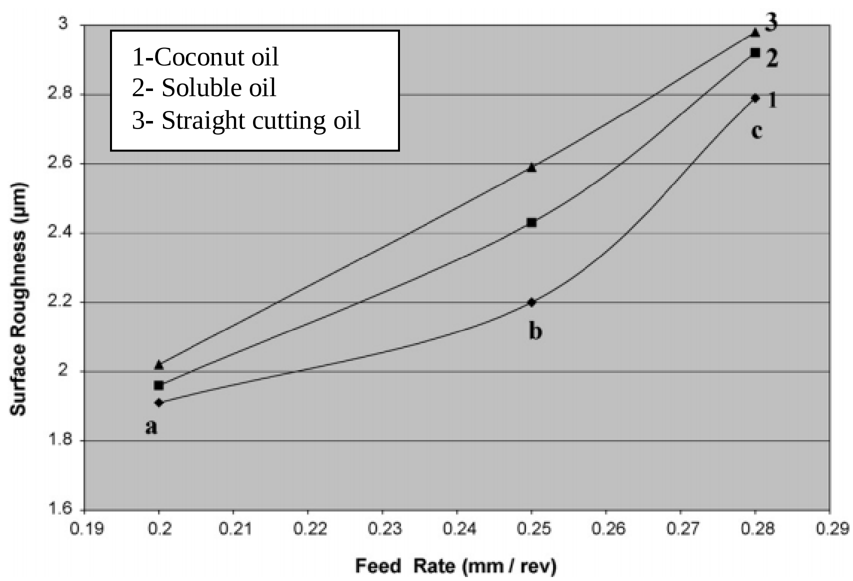


Figure 2.10: Feed rate versus surface roughness, depth of cut (0.5 mm)-constant; cutting speed – 38.95 m/min, 61.35 m/min and 97.38 m/min at the three points a, b ad c respectively [10].

2.6 RESEARCH WORK

Okusa, Yamamoto and Masudomi [4] on the effect of cutting fluid on the surface finish. With the same materials and cutting fluids, the result was found that the surface roughness decrease when the type of chips approached the flow type and a less built-up edge occurred. The effect of the mineral oil base is greater than water and water base.

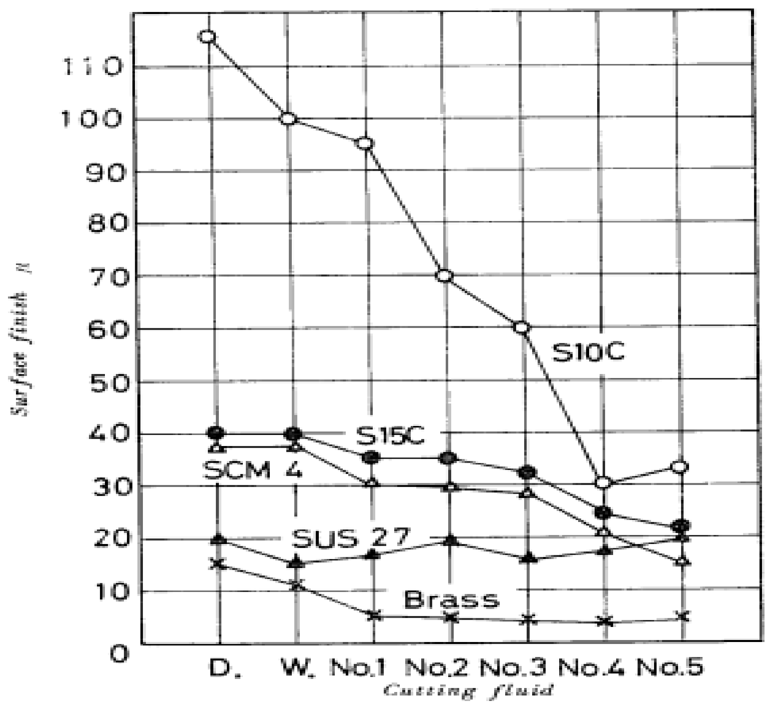


Figure 2.11: Relation between surface finish and cutting fluids [4].

- Note: D (Dry), W (water), No.1- soluble, No. 2 & No. 3 – emulsion , No 4 & No 5 – mineral oil bases.

Junyan, Huanpeng, Rongdi and Yang (2009) [12] had studied on the water vapour as coolant and lubricant in stainless steel cutting. One of the results of their experiment shows machining surface texture is more regular when using water vapor compared to using gas as lubricant (O_2 and CO_2). As there is reduction in cutting force, lowering the friction coefficient and chip deformation coefficient during water vapor application should bring forth better surface roughness value lowering too as seen in Figure 2.12.

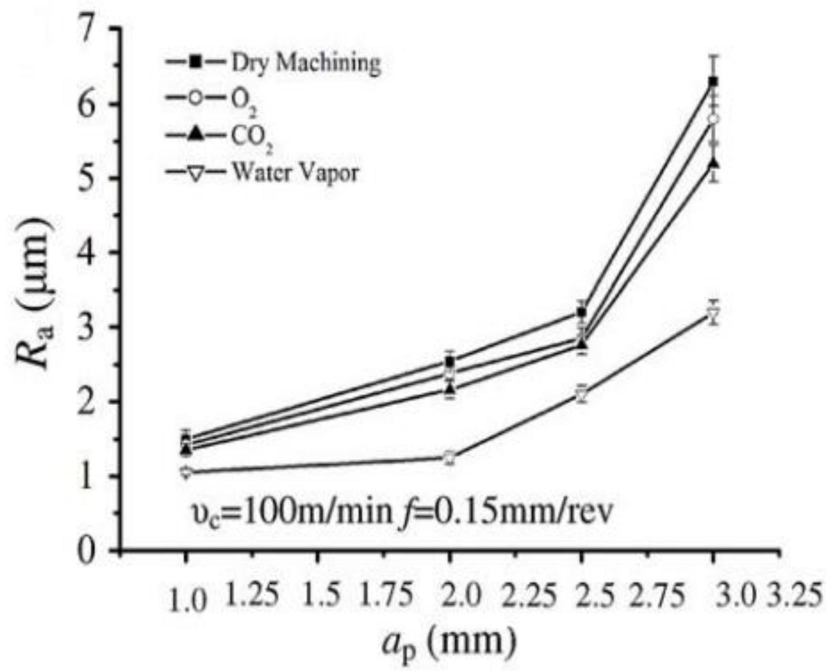


Figure 2.12: Water vapor gives better result compare to dry machining and gas as lubricant [12]

Eduardo *et al* (2003) [16] had analyzed the influence of infeed rate and cutting fluid on cylindrical grinding. In their study, they used two different coolant which were 5% emulsion and pure oil. Roundness error and surface roughness were those parameters analyzed and they revealed that pure oil was the best cutting fluid to improve roundness and surface roughness. They also stated that vibration forces generated by the unstable spindle wheel motor might cause the roundness errors. They also indicated that the emulsion displayed a higher overall roundness error as shown in Figure 2.13. This graph explained the lower roundness errors using pure oil were attributable to the higher lubricating power of this fluid. In other words, the lubricating power of pure oil lead to improved roundness.

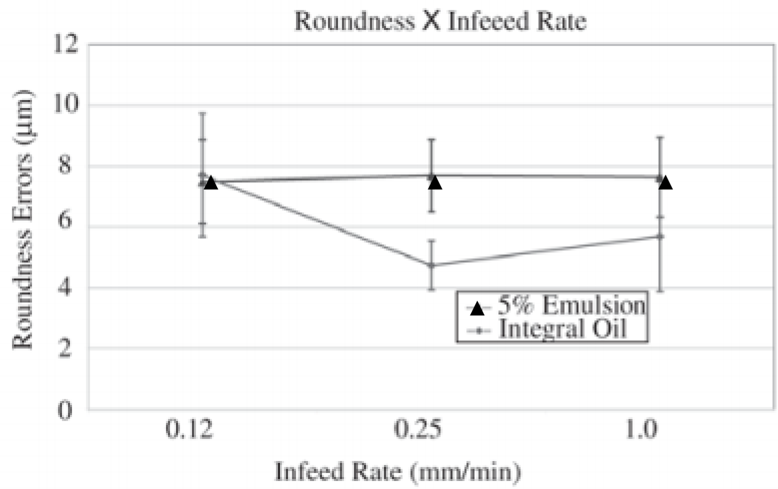


Figure 2.13: Comparison of grinding fluids as a function of roundness error [16]

The same thing went to surface roughness. Eduardo and others were able to prove that workpiece roughness was considerably better when pure oil was used.

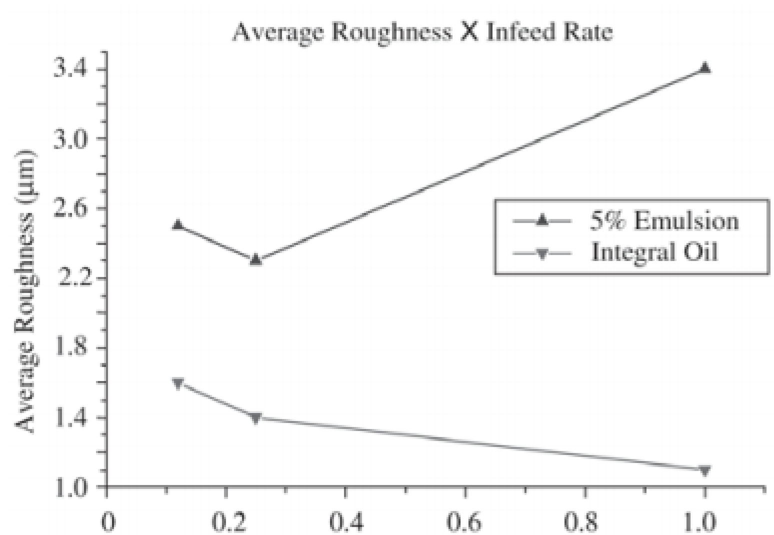


Figure 2.14: Roughness behavior versus infeed rates [16]

CHAPTER 3
METHODOLOGY

3.1 FLOW-CHART

Mainly, this study will be carried out experimentally by using conventional lathe machine. Before conducting the experiment, several parameters and conditions must be fixed first. The concept and requirements of the research must be further understood by referring to the published journals and papers. Sources from books and website are also taken into account to enrich the knowledge on the turning process. After experiments are performed, the data will be analyzed and interpreted. The summary of project work flow is shown in Figure 3.1.

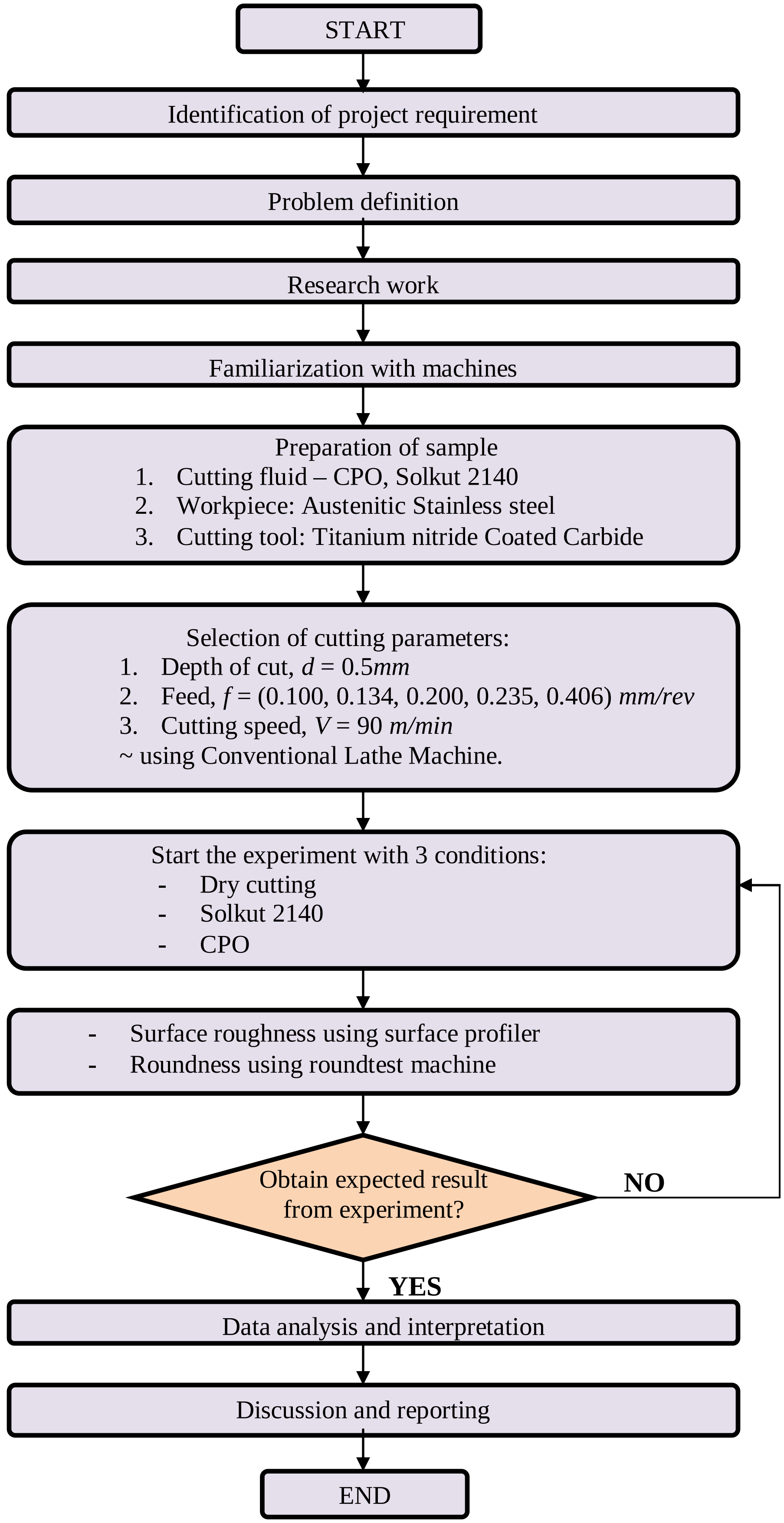


Figure 3.1: Flow chart of project

3.2 MACHINING PARAMETERS

3.2.1 Parameters of Turning Operation

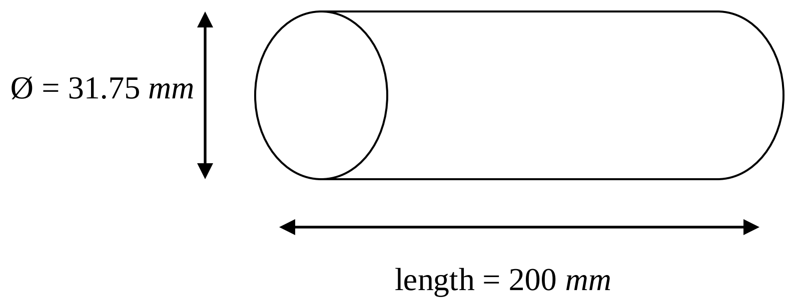


Figure 3.2: Example sample of workpiece.

Table 3-1: Parameters during experiment

Cutting fluids	- CPO - Solkut 2140
Workpiece material	Austenitic Stainless Steel
Cutting Tool	Titanium nitride (TiN) coated carbide
Depth of cut, *d*	0.5*mm*
Cutting Speed, *V*	90 *m/min*
Feed, *f*	0.100 *mm/rev*, 0.134 *mm/rev*, 0.200 *mm/rev*, 0.235 *mm/rev* and 0.406 *mm/rev*
Machine used	- Conventional Lathe Machine - Surface profiler (Perthometer Concept) Mahr PGK 120 - Roundness Testing Machine, Mitutoyo RA-114

During facing (Ø = 31.75 *mm* , *V* = 150 *m/min*)

Depth of cut = 0.25 *mm*

Rotational speed of spindle, *N*

$$N = \frac{V}{\Pi d}$$

$$= \frac{150\ m/min}{\Pi\ (0.03175m)}$$

$$= 1504\ rpm (\sim 1320\ rpm)$$

During roughing (Ø= 31.25 *mm* , *V* = 90 *m/min*)

With depth of cut = 0.25 *mm* during the facing, the new diameter for roughing is 31.25 *mm*.

Rotational speed of spindle, *N*

$$N = \frac{V}{\Pi d}$$

$$= \frac{90\ m/min}{\Pi\ (0.03125\ m)}$$

$$= 917\ rpm\ (\sim 835\ rpm)$$

All these parameters will be used during the turning operation and are referred to the standard in Appendix 3.1. For the starting purpose, the workpiece will be facing in order to remove the impurities such as grease, dust etc. that could effect the force measured. During the facing, the cutting speed required by standard is 150 *m/min* thus the spindle speed required is 1504 rpm. However, the conventional lathe machine does not have the exactly required spindle speed. Thus, the spindle speed will be set at the nearest point (1320 *rpm*). The same thing goes to roughing process where the spindle speed will be set at 835 *rpm* according to machine capabilities. The turning operation will be not repeated for each condition due to cost and material restrictant. Thus, the total of experiment will be 15 experiments. *Refer to Appendix 3.2 for turning procedure.*

3.2.2 Surface Roughness

A surface profiler will be used to measure the surface roughness of the turning workpiece. For the accuracy of the measurement, the turned parts will be divided into 3 segments as shown in figure below. Then the workpiece will be measured at three different points with 3 different measurement lengths (10 *mm*, 20*mm*, 30*mm*). *Refer to Appendix 3.4 for surface roughness procedure.*

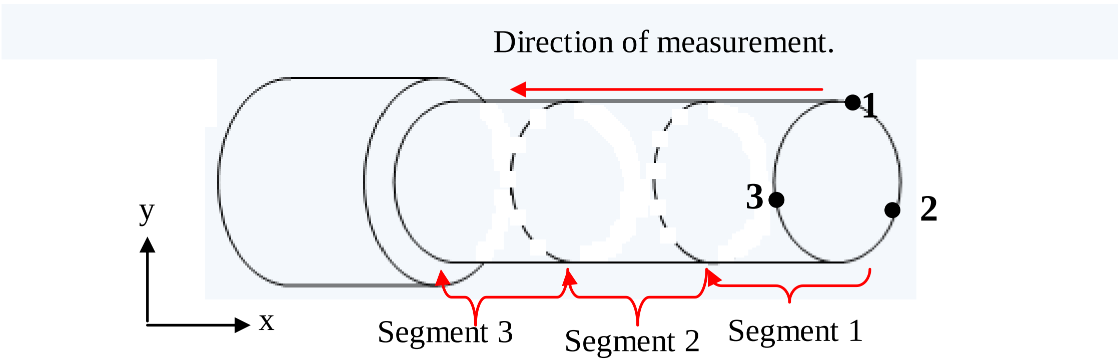


Figure 3.3: Point to be measured on the sample.

3.2.3 Roundness Measurement

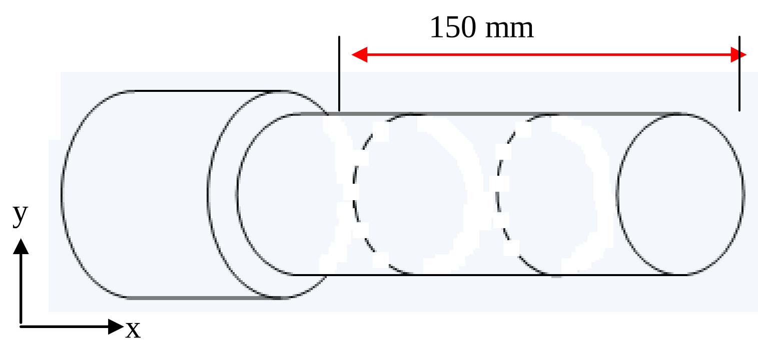


Figure 3.4: Three segments for round test

In roundness measurement, the workpiece will be segmented into 3 segments as in surface roughness. Then the roundness measurement will be determined on each of segment. So there will be 3 reading of roundness for each workpiece and average of it will be calculated. *Refer to Appendix 3.5 for roundness procedure.*

3.3 MATERIAL PROPERTIES

3.3.1 Cutting Tool Specifications

Commercial name	: Titanium-nitride coated carbide
Coding	: CNMG 120408 – MS US735
Inert shape	: Rhombic 80°
Chip breaker	: Cylindrical on both sides
Thickness	: 4.76 mm
Hardness	: 180 HB
Thermal conductivity	: 29 (W/m-k)
Thermal expansion	: 9.4 * 10^{-8} $(K)^{-1}$ [19]

3.3.2 Workpiece Properties

AISI 304 Stainless steel

Density	: 8.00 g/cc
Hardness (Brinell)	: 138 HB
Ultimate tensile strength	: 505 MPa
Yield tensile strength	: 215 MPa
Modulus of elasticity	: 193-200 GPa
Shear modulus	: 86.0 GPa
Specific heat capacity	: 0.500 J/g-°C
Melting point	: 1400-1455°C
Composition	: <= 0.080% (carbon), 18-20% (chromium)
Material note	: Austenitic Cr-Ni stainless steel. Better corrosion resistance than Type 302. High ductility, excellent drawing, forming, and spinning properties. Essentially non-magnetic, becomes slightly magnetic when cold worked. Low carbon content means less carbide precipitation in the heat-affected zone during welding and a lower susceptibility to intergranular corrosion.
Corrosion Resistance	**:** Resists most oxidizing acids and salt spray [20]

3.4 MATERIAL PREPARATION

The source of CPO is from palm oil factory of FELCRA Nasaruddin located at Bota, Perak. Starting with sterilization process, the palm fruit is then extracted and finally undergo the purification process to produce crude palm oil. *Refer to Appendix 3.6 for palm oil process.*

CPO is easily to get viscous (semisolid) at low temperature. At this point, its color would change from reddish to yellow as shown in Figure 3.5 below. Due to its semisolid properties, CPO must be reheated first before being used during lathe operation.

Figure 3.5: Actual reddish color of CPO at high temperature.

Figure 3.6: CPO turned to yellow at low temperature.

Figure 3.7: Five pieces of austenitic stainless steel before turning operation.

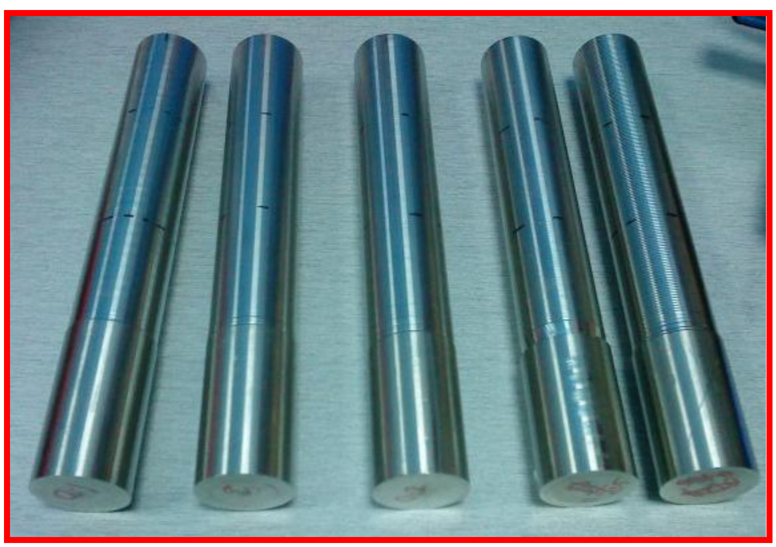


Figure 3.8: Workpieces after turning.

3.5 CPO APPLICATION METHOD

There are 4 basic methods of cutting fluid application in machining. They are flooding, mist, high pressure system and through cutting tool system [2]. In this project, the easiest method of applying CPO is either by flooding or mist. However, by considering properties of CPO that easily to get viscous at low temperature, the flooding method is chosen instead of mist.

As shown in the Figure 3.9 below is the method on how to apply CPO. A bottle and a tube are used to flow the CPO. No valve system is used because practically the residue CPO might get stuck inside the valve component. As mention before, CPO will be heated first before being used, thus it will become liquid and easily to flow. However, as time running and temperature become lower, the liquid CPO turn to viscous and refuse to flow. As a solution, no valve is used and CPO is reheated on each time before used.

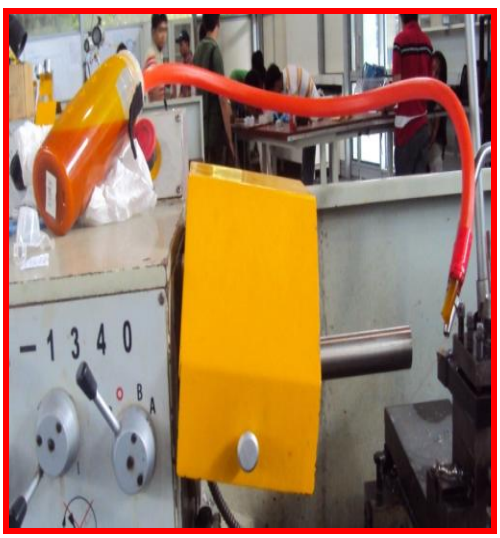


Figure 3.9: CPO application system using bottle and tube.

Figure 3.10: Close view at tool-workpiece interface

3.6 EQUIPMENT USED

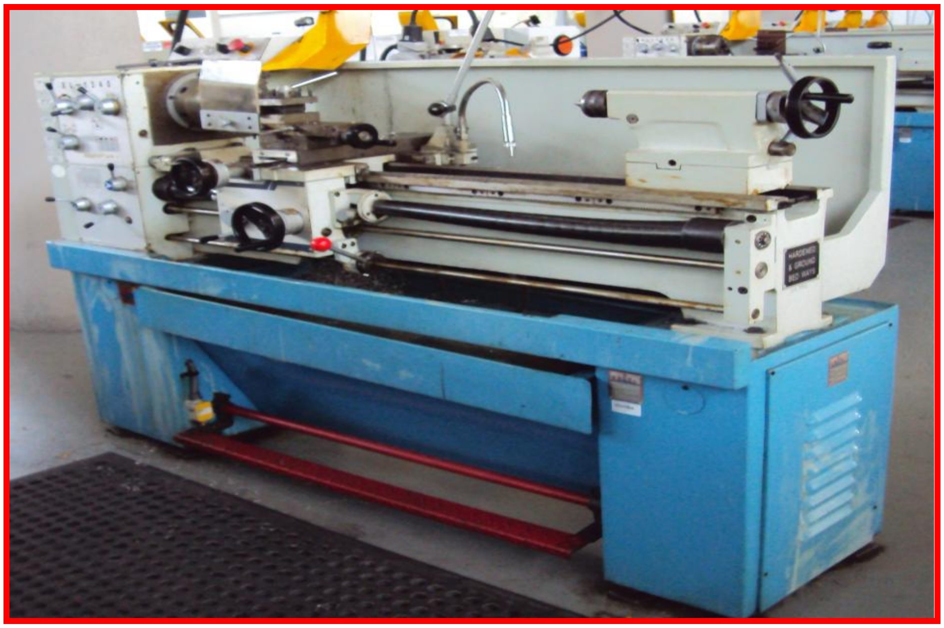


Figure 3.11: Conventional lathe machine

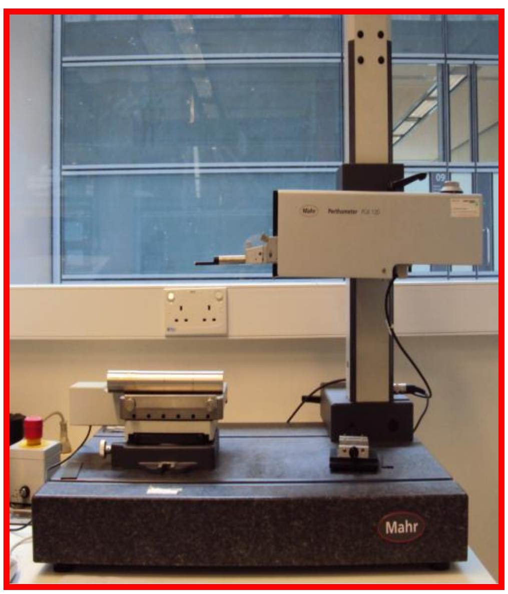


Figure 3.12: Surface profiler machine used to measure surface roughness

Figure 3.13: Roundtest machine used to measure roundness of workpiece.

3.7 GANTT CHART

No	Activity	Week														
		1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project topic								Mid semester break							
2	Research work															
3	Submission of Preliminary Report					▲										
4	Determination of turning operations and parameters															
5	Submission of Progress Report									▲						
6	Seminar									▲						
7	Preparation of sample and cutting tool material ● CPO and Solkut cutting fluid ● Workpiece and cutting tool material															
8	Familiarization of machines															
9	Submission of Interim Report Final Draft															▲
10	Oral Presentation									During study week						

▲	Milestone
	Process

No	Activity	Week														
		1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Preparation of sample							Mid semester break								
	Familiarization of round test machine															
2	Submission of Progress Report 1				▲											
3	Project work continues ● Experimental work ● Measurement of surface roughness ● Measurement of surface roundness															
4	Submission of Progress Report 2									▲						
5	Seminar									▲						
6	Analysis of obtained data															
7	Poster exhibition												▲			
8	Submission of Dissertation Final Draft															▲
9	Oral Presentation								During study week							
10	Submission of Dissertation (hard bound)								7 days after oral presentation							

▲	Milestone
	Process

CHAPTER 4
RESULT AND DISCUSSION

The experiments are successfully finished for the dry cutting and wet cutting with Solkut and CPO. During the turning operation, feed is varying instead of depth of cut because based on the previous research work, feed gives the better significant effect to the surface roughness and roundness. Stainless steel is used in turning operation with parameters as stated in Table 3-1. After conducting the turning, the sample is tested with roughness and roundness testing machine and the results are discussed later.

4.1 TURNING OPERATION

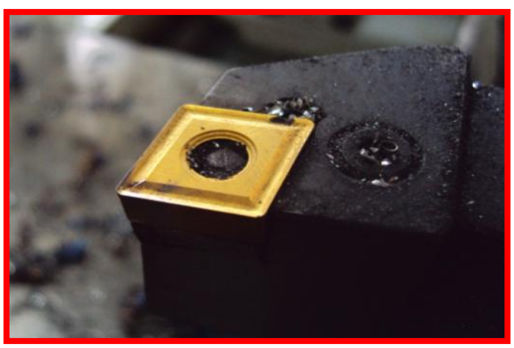


Figure 4.1: TiN-coated carbide cutting tool

Figure 4.2: Dry cutting turning operation

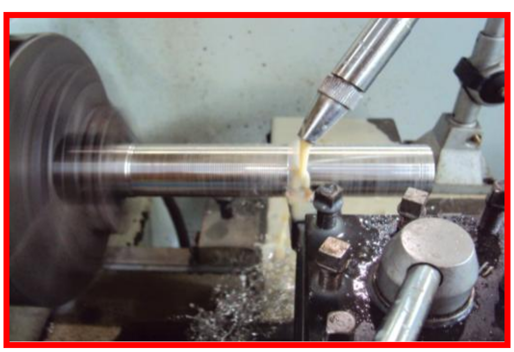
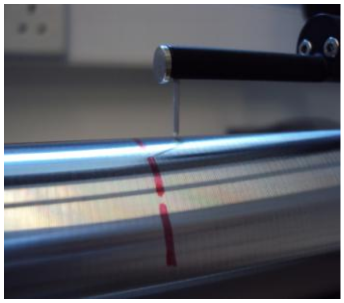
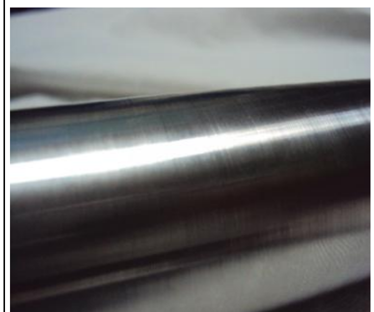
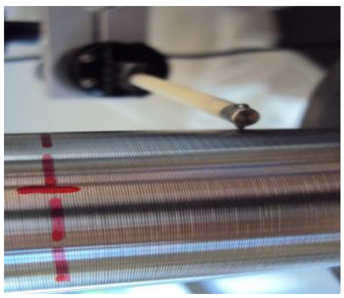
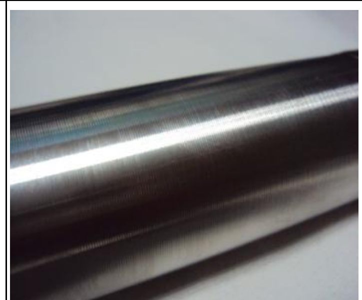
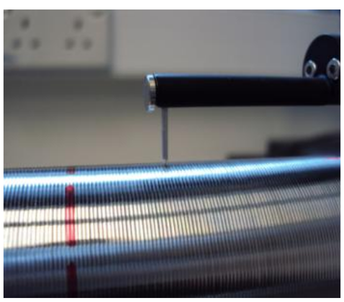
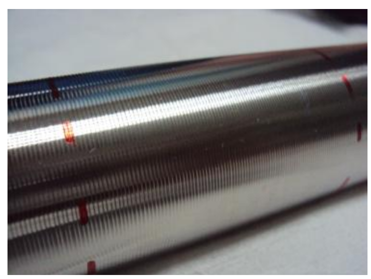
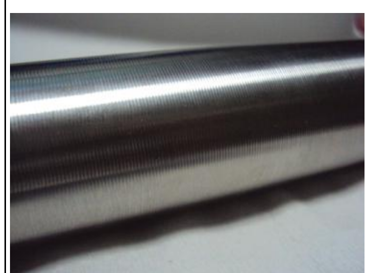
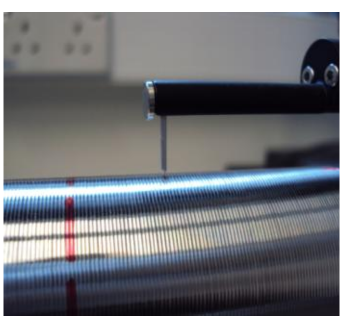
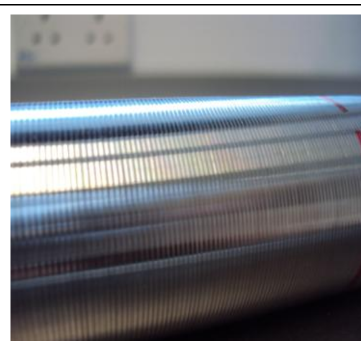
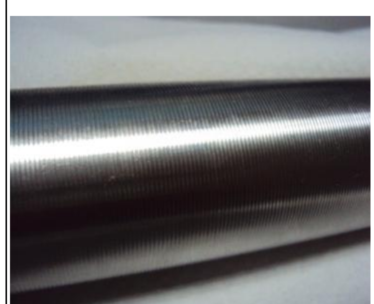
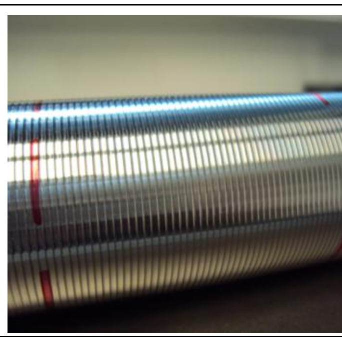
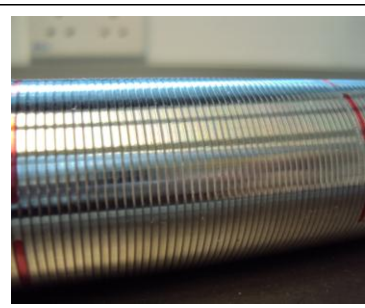
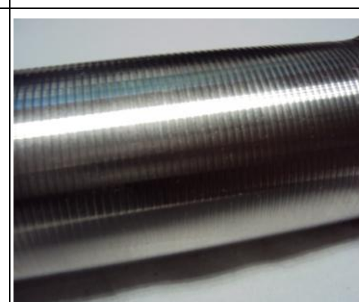


Figure 4.3: Turning with Solkut

Figure 4.4: Turning with CPO

Table 4-1: View of work piece surface after turning

Feed (*mm/rev*)	Dry Cutting	Solkut	CPO
0.100			
0.134			
0.200			
0.235			
0.406			

4.2 SURFACE ROUGHNESS TESTING

As mention in *Section 2.1*, the result of surface roughness measurement can be presented in several ways which are Mean Surface Roughness, ***Ra*** and Mean Roughness Depth, ***Rz***.

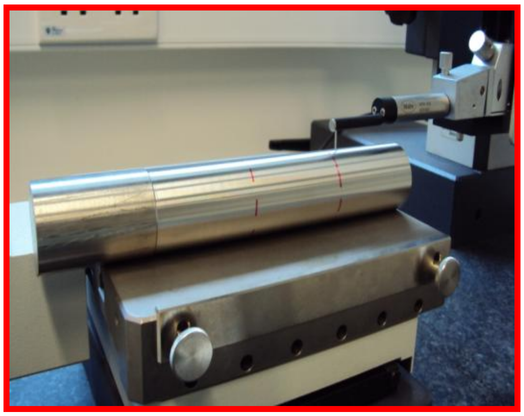


Figure 4.6: Position of sample during the testing

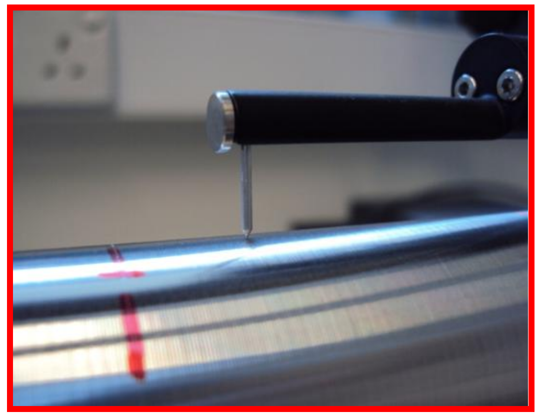


Figure 4.7: Stylus is used to trace the surface profile

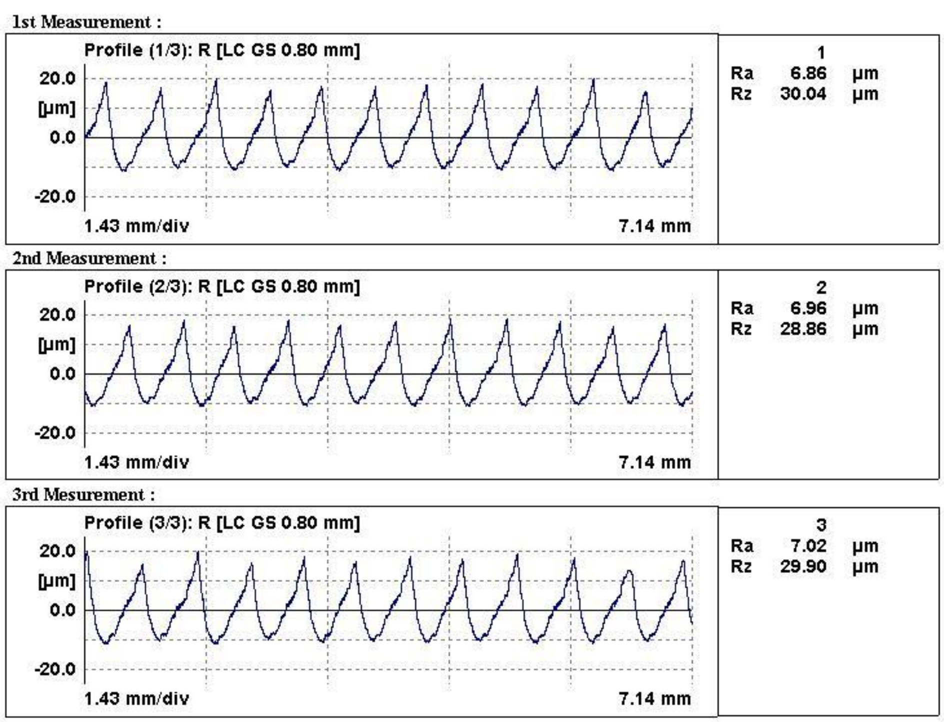


Figure 4.8: Rough data for surface roughness for 0.235 *mm/rev* of feed at 10*mm* measurement length.

4.2.1 Mean Surface Roughness, Ra

Table 4-2: Primary result of mean surface roughness

Feed (*mm/rev*)	Segment	Condition								
		Dry			Solkut			CPO		
		10	20	30	10	20	30	10	20	30
0.100	1	3.42	3.75	3.78	3.34	3.34	3.34	2.80	3.13	3.18
	2	3.56	3.82	3.87	2.73	3.02	2.90	2.76	2.84	2.87
	3	3.60	3.89	3.94	3.31	3.84	3.67	2.79	3.27	3.30
0.134	1	5.15	5.61	5.56	4.82	6.49	5.38	4.49	4.74	4.69
	2	5.32	5.64	5.61	4.89	5.27	4.76	4.44	4.68	4.62
	3	5.28	5.68	5.66	3.97	4.56	4.95	4.44	4.68	4.63
0.200	1	6.84	9.14	9.02	7.40	10.17	10.02	6.59	8.29	8.33
	2	7.03	9.21	9.25	7.35	8.76	8.51	6.55	8.23	8.31
	3	7.13	9.25	9.21	6.64	8.46	9.18	6.61	8.08	8.11
0.235	1	6.73	9.41	9.32	7.07	11.64	10.93	6.92	10.12	10.09
	2	7.37	10.47	10.29	6.98	9.51	9.60	6.88	10.21	10.18
	3	7.70	11.13	11.25	6.79	11.30	10.75	6.95	10.13	10.18
0.406	1	7.95	23.74	23.77	7.32	23.16	22.08	4.44	10.05	12.03
	2	7.82	23.60	23.73	7.29	20.80	19.87	4.45	11.89	10.93
	3	7.82	23.25	23.51	7.38	19.98	20.94	3.94	10.56	10.25

Table 4-3: Average mean surface roughness

Feed (*mm/rev*)	Dry cutting			Solkut			CPO		
	Length of Measurement (*mm*)								
	10.00	20.00	30.00	10.00	20.00	30.00	10.00	20.00	30.00
0.100	3.53	3.82	3.86	3.13	3.40	3.30	2.78	3.08	3.12
0.134	5.25	5.64	5.61	4.56	5.44	5.03	4.46	4.70	4.65
0.200	7.00	9.20	9.16	7.13	9.13	9.24	6.58	8.20	8.25
0.235	7.27	10.34	10.29	6.95	10.82	10.43	6.92	10.15	10.15
0.406	7.86	23.53	23.67	7.33	21.31	20.96	4.28	10.83	11.07

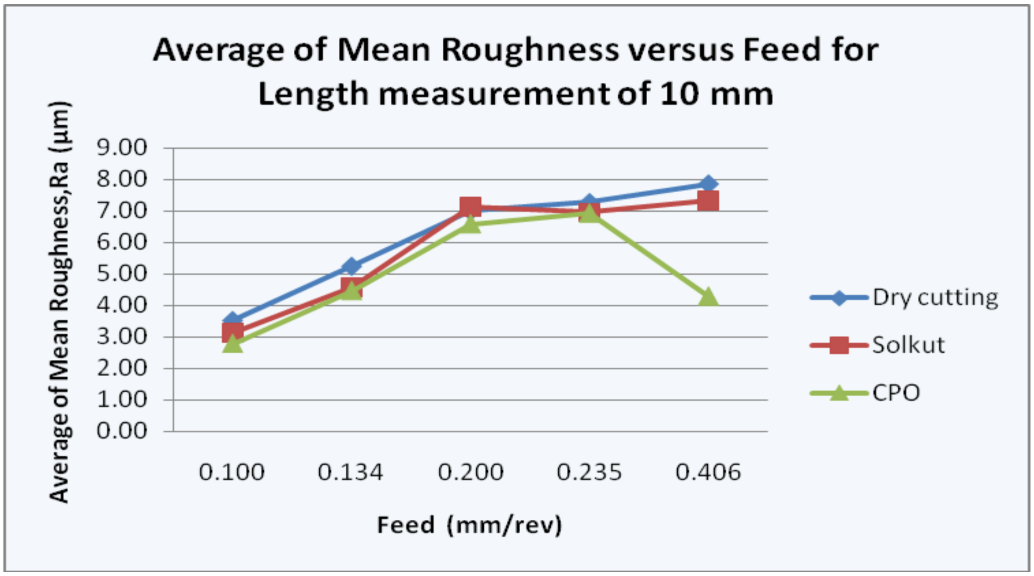


Figure 4.9: Graph of mean surface roughness versus feed for
10*mm* length measurement

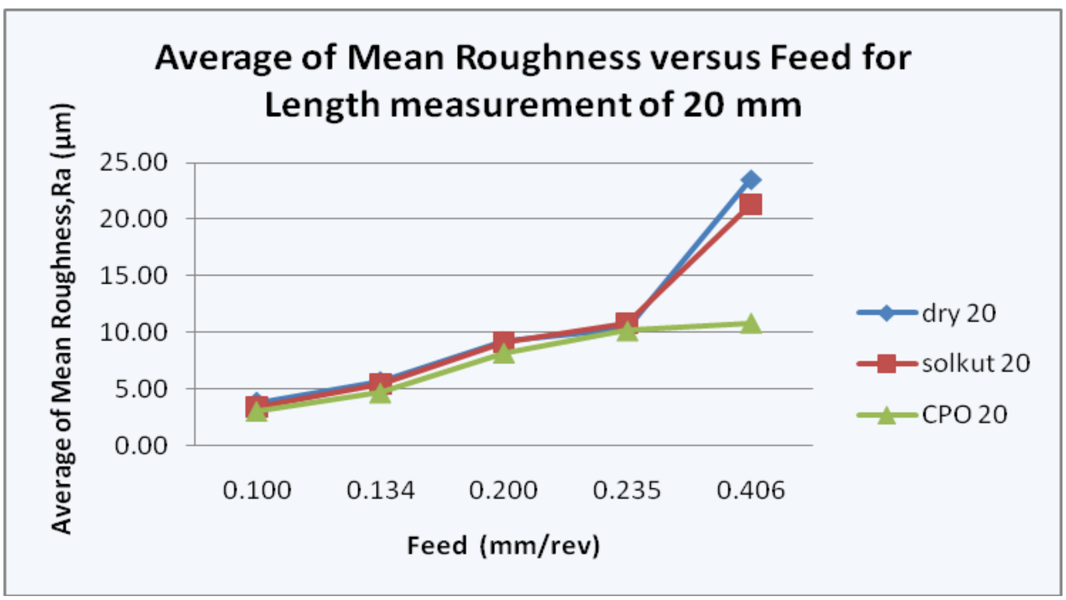


Figure 4.10: Graph of mean surface roughness versus feed for
20*mm* length measurement

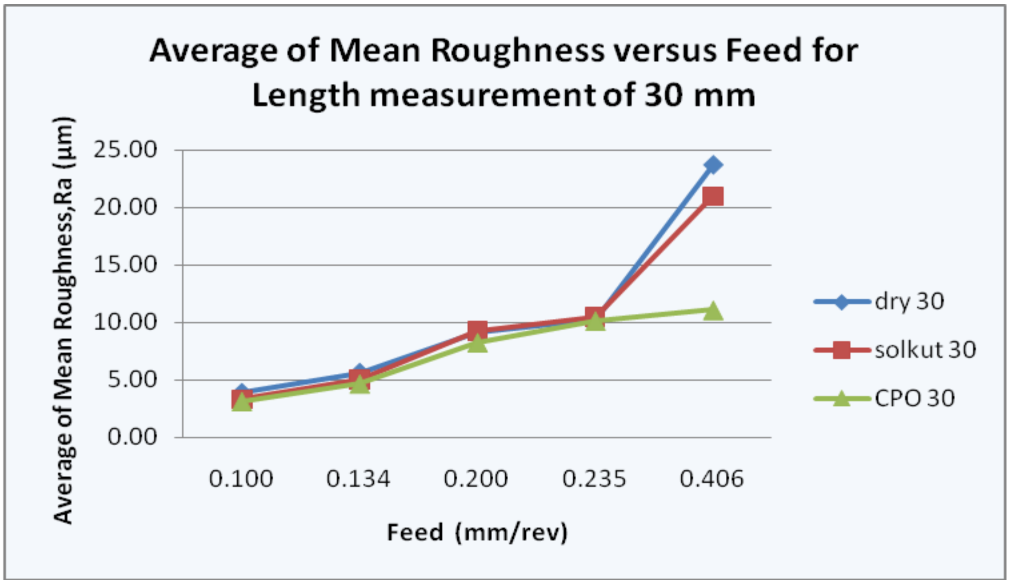


Figure 4.11: Graph of mean surface roughness versus feed for 30*mm* length measurement

The Table 4-2 shows the primary result of **mean surface roughness**, ***Ra*** for turning with dry cutting and turning with Solkut and CPO. Roughly from these data, it slightly shows the positive changes of surface roughness when sample is turned by using Solkut and CPO instead of dry cutting. The average of roughness is shown in Table 4-3. By considering the range of waviness, the average of roughness is taking for the measurement length of 10*mm*, *20mm* and 30*mm*. These averages are then used to plot the graph as in Figure 4.8, Figure 4.9 and Figure 4.10. From these graphs, it is clearly illustrate that by increasing the feed, the mean surface roughness of sample also increase for all conditions. However, surface roughness is improved when Solkut and CPO are used during turning. These shows performance of CPO is good as Solkut in improving surface roughness.

As shown in Equation 2.1 and Figure 2.4 in *Section 2.1*, ***Ra*** is referring as mean surface roughness or arithmetic mean roughness. ***Ra*** is the value obtained by that formula and expressed in micrometer (μm) when sampling only the reference length from the roughness curve in the direction of the mean line. During the testing using surface profiler, the stylus is moving along the longitudinal direction (*x*-axis, refer to Figure 3.3) of cylindrical workpiece. Due to the cylindrical shape of workpiece, the surface roughness only can be measure in one direction compare to rectangular workpiece used in milling which can be accessed in X and Y direction.

In determining the surface roughness of the workpiece, 'length of measurement' of stylus travel is also taking into consideration. Length of measurement or refers as 'travelling length' in contact of surface roughness parameters, is defined as the overall length travelled by the stylus when acquiring the traced profile. In this testing, there are three different travelling length set which are 10*mm*, 20*mm* and 30*mm*.

By referring to Figure 4.5, it shows the rough data of surface roughness 0.235 *mm/rev* of feed at 10*mm* travelling length, where the three measurements are taken. The *y*- axis of the graph refers to the surface roughness value in micrometer (μm). In the graph, the range of surface roughness is between 20 μm to -20 μm. While *x*- axis value is 7.54*mm* refers to the 'evaluation length', **(l_n),** defined as the part of the traversing length from where the values of the surface parameters are determined. Another term that important is 'sampling length', (l_r) defined as the reference for roughness evaluation. Back to the figure, l_n at 7.14*mm* has been divided into 5 sampling division. Each length of division valued 1.43 *mm/div* and this length is referred as sampling length, l_r. Although the stylus has been set to travel at 10*mm* but only 7.54*mm* of the length will be evaluated.

The graphs plotted above are not only showing the comparison of mean surface roughness, ***Ra*** between dry cutting, Solkut and CPO but they also differ in 'length of measurement' or travelling length as mention above. Refer to Table 4-3 at 10*mm* and Figure 4.8, ***Ra*** is increasing with increasing of feed but the range of ***Ra*** is decreasing from dry cutting to CPO. From feed 0.100*mm/rev* to 0.406*mm/rev* the ***Ra*** range ***is*** between 3.53μm – 7.86μm for dry cutting, 3.13μm – 7.33μm for Solkut and 2.78μm – 6.92μm for CPO. The same results are obtained for travelling length of 20*mm* and 30*mm* where the roughnesses are getting increase in larger roughness profile scale. It can be concluded turning with Solkut and CPO show better performance compare to dry cutting.

Stainless steel is slightly difficult to be machined due to its high material properties. That is why titanium nitride coated carbide is used as cutting tool which has greater hardness than stainless steel. Without cutting fluid in machining, it resulted in high friction at tool-chip interface and finally produce bad surface of workpiece. Using Solkut and CPO are able to improve surface roughness as shown in data of results above. Solkut, a mineral cutting fluid as CPO but comes in package of additives and stabilizers resulting as emulsion cutting fluid.

4.2.2 Mean Roughness Depth, Rz

Table 4-4: Primary result of mean roughness depth

Feed (mm/rev)	Segment	Condition								
		Dry			Solkut			CPO		
		10	20	30	10	20	30	10	20	30
0.100	1	15.76	20.34	20.83	16.42	18.11	18.95	14.90	17.78	20.03
	2	16.06	20.51	20.74	13.29	17.54	17.71	13.57	15.17	16.34
	3	16.45	21.13	22.02	16.57	21.97	21.42	14.49	17.55	18.79
0.134	1	21.82	28.32	29.10	22.36	30.92	28.79	19.59	23.41	24.32
	2	22.56	28.01	29.26	21.85	27.24	26.96	19.47	22.98	22.99
	3	22.50	28.55	29.26	18.46	23.53	25.82	19.19	22.25	22.52
0.200	1	29.16	43.66	44.40	30.99	44.18	45.22	26.70	35.65	37.17
	2	30.84	44.72	45.43	30.58	37.48	38.09	26.26	33.45	35.57
	3	30.13	42.27	43.99	27.95	38.97	43.14	27.19	33.97	35.45
0.235	1	28.86	39.94	40.54	30.94	47.34	47.06	29.78	41.79	43.51
	2	30.69	43.62	44.68	29.77	41.36	41.68	29.18	42.03	41.69
	3	31.44	45.27	46.74	29.69	47.32	45.45	29.60	40.81	41.47
0.406	1	47.25	93.11	93.37	46.04	87.61	87.09	22.14	42.24	48.26
	2	48.15	93.00	94.23	43.05	80.29	78.40	22.25	44.16	43.88
	3	46.12	91.36	94.29	41.52	78.24	80.72	20.46	41.52	41.02

Table 4-5: Average of mean roughness depth

Feed (mm/rev)	Dry cutting			Solkut			CPO		
	Length of Measurement (mm)								
	10.00	20.00	30.00	10.00	20.00	30.00	10.00	20.00	30.00
0.100	16.09	20.66	21.20	15.43	19.21	19.36	14.32	16.83	18.39
0.134	22.29	28.29	29.21	20.89	27.23	27.19	19.42	22.88	23.28
0.200	30.04	43.55	44.61	29.84	40.21	42.15	26.72	34.36	36.06
0.235	30.33	42.94	43.99	30.13	45.34	44.73	29.52	41.54	42.22
0.406	47.17	92.49	93.96	43.54	82.05	82.07	21.62	42.64	44.39

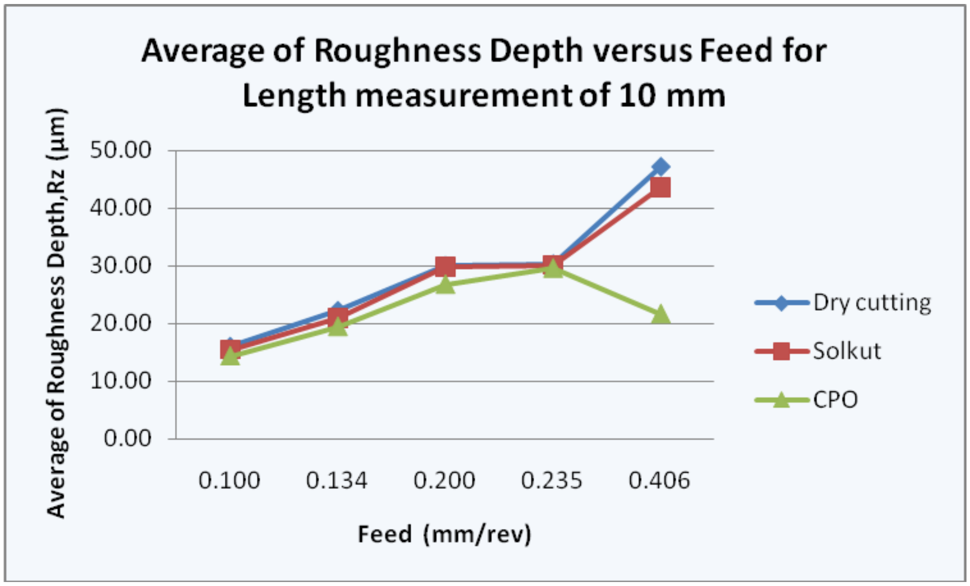


Figure 4.12: Graph of mean roughness depth versus feed for 10mm length measurement

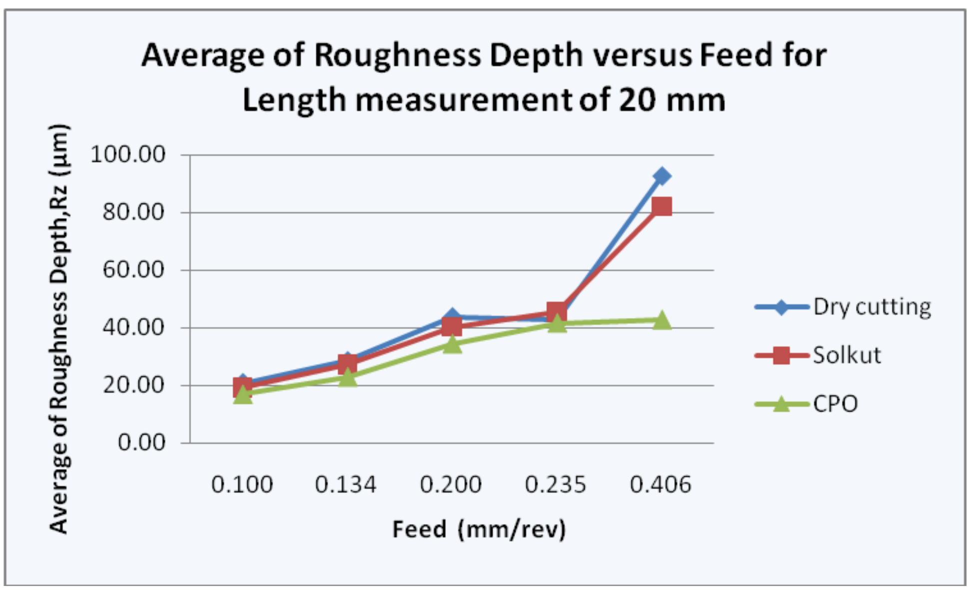


Figure 4.13: Graph of mean roughness depth versus feed for 20mm length measurement

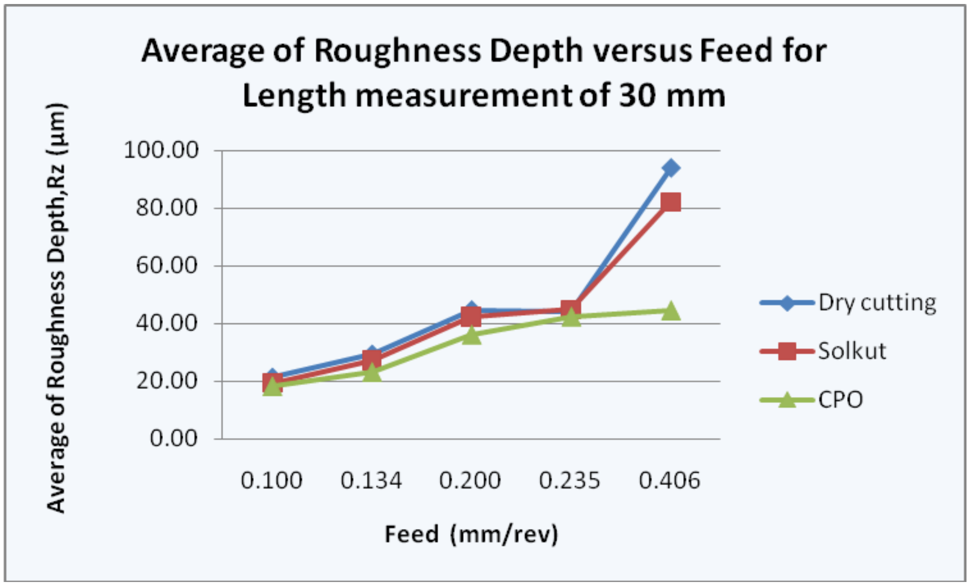


Figure 4.14: Graph of mean roughness depth versus feed for 30mm length measurement.

Same as in *Section 4.2.1*, the primary data of **mean roughness depth**,***Rz*** shown in Table 4-4. Graphs in above figures are plotted from the average value calculated in Table 4-5. From the graphs, they clearly show increasing of mean roughess depth when the feed is increased. It has the same increasing trend with the ***Ra*** but only differ in value where ***Rz*** is higher than ***Ra***.

Mean roughness depth ,Rz can be defined as the height from the deepest valley to the highest peak. It indicates how much material has to be removed on order to obtain smooth surface. By referring to the Figure 2.7 in *Section 2.1*, ***Rz*** shall be that only when the reference length is sampled from the roughness curve in the direction of mean line, the distance between the top profile peak line and the bottom profile valley line on this sampled portion is measured in the longitudinal magnification direction of roughness curve and the obtained value is expressed in micrometer.

The results for ***Rz*** are almost same with ***Ra*** with increasing feed for Solkut as well as CPO. It is also give similar results when varying the travelling length from 10*mm* to 30*mm*. It can be said the performance of CPO is better than Solkut. For example, at travelling length of 10*mm*, the range of ***Rz*** for dry cutting is between 16.09μm – 47.17μm, Solkut around 15.43μm – 43.54μm and CPO in between 14.32μm – 29.32μm.

High ductility, high strength, high work hardening rate and low thermal conductivity of stainless steels are the main factors that make their machinability difficult. However its corrosion resistance properties make it easier to handle compare to mild steel.

Machining a stainless steel workpiece without any cutting fluid is very difficult because it can result in high stress and a thick adhering layer at tool-work interface [12]. Solkut, soluble oil which is mixture of oil and water and CPO, the pure mineral oil are the cutting fluid used in this experiment. By using cutting fluid, firmer boundary lubrication is formed at tool-chip interfaces and lower the cutting force thus improve surface finished.

In boundary lubrication, the force is supporting by contacting surfaces covered with a boundary film of lubricant. It is a thin molecular lubricant layer that is attracted physically to the metal surfaces, thus preventing direct tool-workpiece contact and reducing wear.

As expained above and in section before, surface roughness can be presented in two ways either by measuring is roughness form main line (Ra) or roughness depth (Rz). In general, a surface cannot be describe by its Ra or Rz value alone, since these value are averages. Two surface may be have the same roughness but have the actual topography which is very different.

4.3: ROUNDNESS TESTING

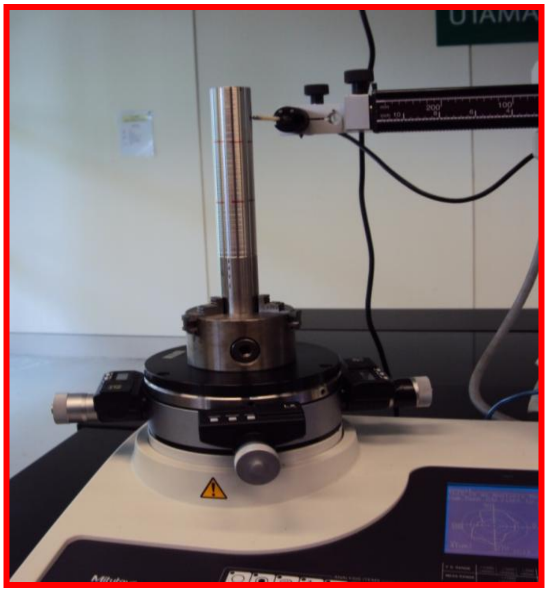


Figure 4.15: Position of sample on the roundtest machine

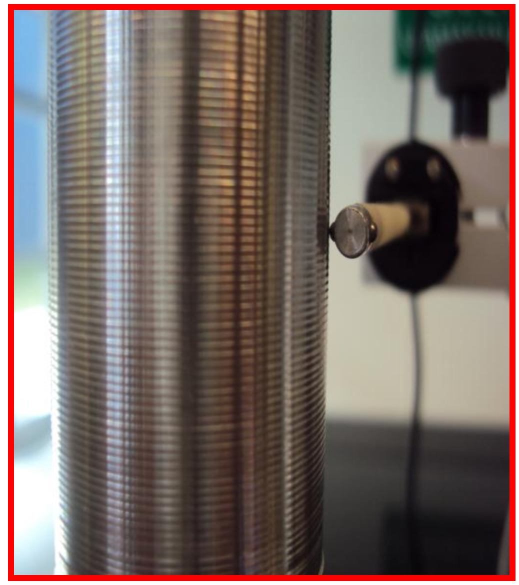


Figure 4.16: A standard stylus used to trace the surface roundness

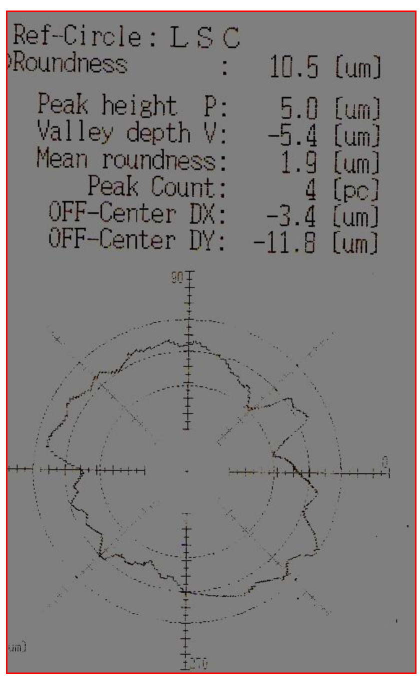


Figure 4.17: Roundness result

Table 4-6: Primary result of roundness test

Feed (mm/rev)	Segment	Condition								
		Dry			Solkut			CPO		
		reading 1	reading 2	reading 3	reading 1	reading 2	reading 3	reading 1	reading 2	reading 3
0.1	1	17.70	15.50	22.30	7.00	5.70	5.70	17.40	16.10	10.30
	2	12.50	10.80	14.60	7.20	3.60	8.50	9.20	8.20	6.00
	3	8.10	9.40	5.00	11.20	8.40	9.50	6.40	7.70	6.50
0.134	1	8.10	10.20	7.80	24.80	36.70	22.50	24.80	20.10	11.30
	2	6.90	6.40	10.80	25.60	22.00	30.30	10.20	5.80	6.10
	3	8.00	5.10	6.80	14.10	8.80	9.40	6.70	5.40	5.70
0.2	1	34.10	33.00	25.60	8.40	13.40	19.20	19.80	18.10	12.30
	2	15.20	15.80	18.30	15.90	12.60	16.50	17.20	9.00	12.40
	3	11.60	11.60	10.90	12.00	27.40	19.40	11.30	8.80	8.30
0.235	1	27.90	24.40	19.10	12.50	9.60	19.10	78.40	85.10	69.20
	2	26.50	20.50	19.10	7.80	16.80	13.20	38.80	15.90	8.40
	3	15.00	22.50	14.20	12.30	21.60	23.50	9.40	12.30	12.20
0.406	1	29.30	21.90	46.60	26.30	31.00	30.50	9.80	10.40	16.30
	2	21.50	39.70	22.60	22.30	28.70	29.60	24.00	7.50	22.20
	3	33.40	25.80	25.10	32.20	26.70	26.30	26.90	12.00	33.60

Table 4-7: Average surface roundness

Feed (mm/rev)	Dry Cutting	Solkut	CPO
0.100	12.88	7.42	9.76
0.134	7.79	21.58	10.68
0.200	19.57	16.09	13.02
0.235	21.02	15.16	36.63
0.406	29.54	28.18	18.08

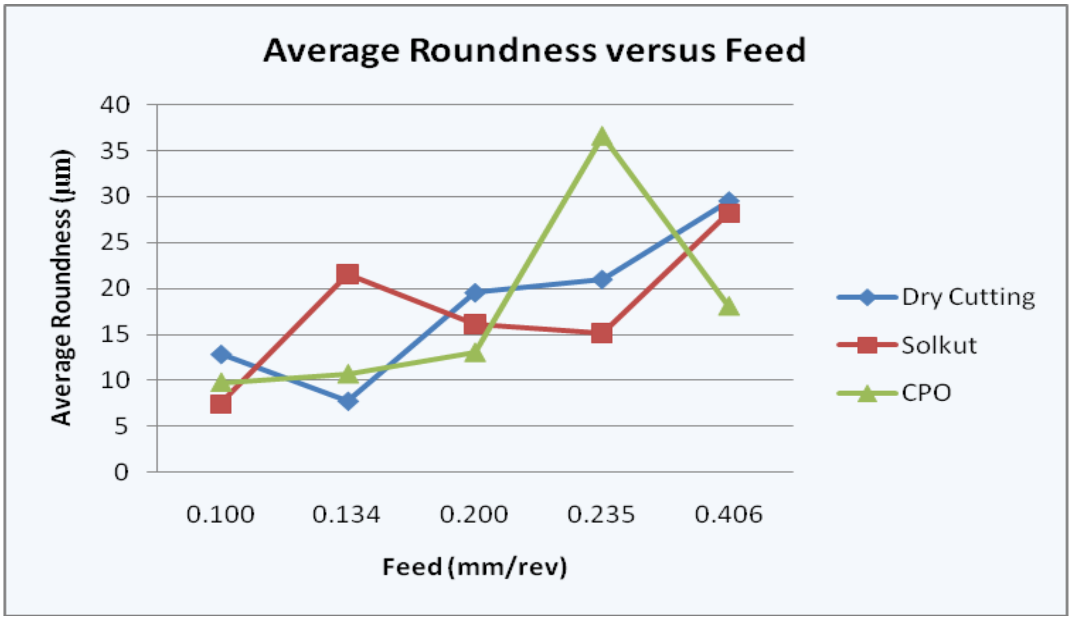


Figure 4.18: Graph of average surface roundness versus feed

Same as surface roughness, the average of roundness is calculated as shown in Table 4-7. A graph is plotted showing the performance of turning with dry cutting, Solkut and CPO in term of roundness of stainless steel workpiece. Averagely, it shows roundness values increase by increasing of feed and CPO has shown good performance as Solkut as cutting fluid. From the graph, it is also seen that at feed value of 0.100 *mm/rev*, 0.200 *mm/rev*, 0.235 *mm/rev* and 0.406 *mm/rev*, show lower roundness value for turning with Solkut instead of dry cutting as expected. However, for feed at 0.134 *mm/rev* the roundness result is not as expected and it is believed due to machine error. The same thing goes to CPO at feed of 0.235*mm/rev*, where it roundness value is out of range. It is also believed due to machining error.

The roundness result for dry cutting is taken as the reference point. The range of roundness is between 7.79 μm – 29.54 μm. For turning with Solkut, the range is between 7.42 μm – *28.18* μm. While for CPO, the roundness range is between 9.76 μm – 18.08 μm. At 0.235 *mm/rev* feed for CPO, the roundness is 36.63 μm and is considered out of range.

Roundness of the workpieces are measured using Round-Test Machines (Figure 3.13). The work piece is clamped at the clamping table and it rotates while stylus is touching the workpiece and measure the roundness as shown in Figure 4.14 and Figure 4.15. There are nine readings taken from each workpiece at different location. As shown in Figure 3.4, the 150*mm* turned stainless steel is divided into three segments. For each segment, 3 reading of roundness are taken, so the total is nine readings. Then the averages of roundness are calculated and graphs are plotted.

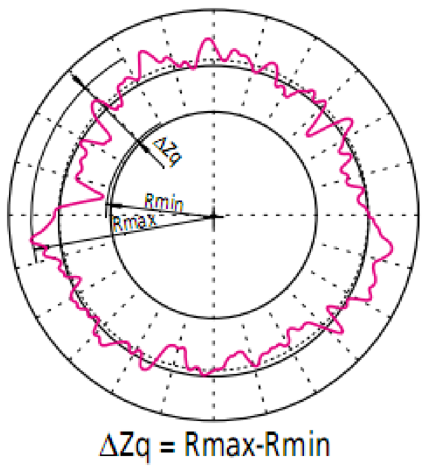
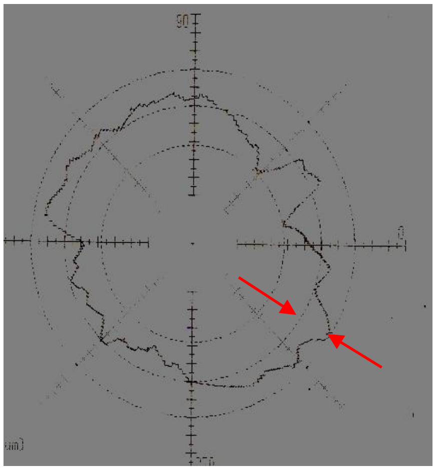
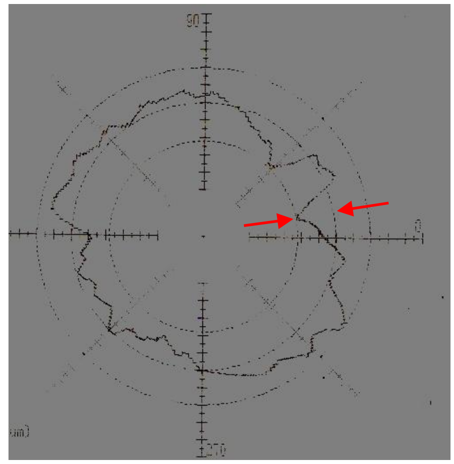
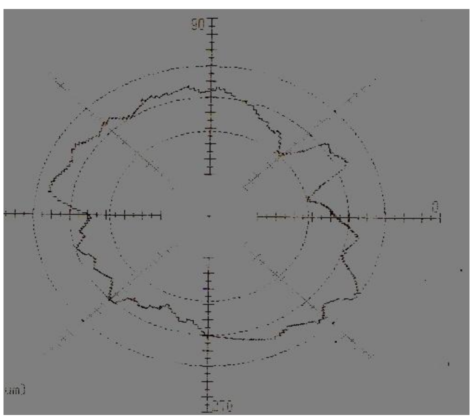
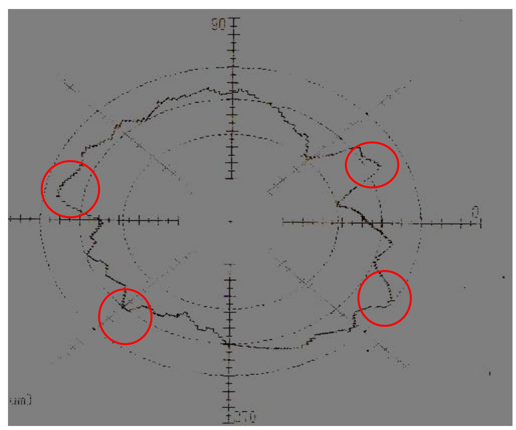


Figure 4.19: Sketch of a profile [8]

Roundness is calculated from the least square circle (LSC) method where a circle is fitted to the measured profile such that the sum of the square of the departure of the profile data from this circle is a minimum. The roundness figure is defined as the difference between the maximum departures of the profile from this circle (highest peak to the lowest valley) as shown in Figure 4.19 above [8].

The printed output result of roundness measurement is shows in Figure 4.17. as shown on the figure, the roundness is 10.5 μm using LSC method. Other parameters such as peak height, valley depth and peak count are shown in Table 4-8 on next page.

Table 4-8: Point of parameters reading are taken.

Peak height	Valley depth
 Peak height = 5.0 μm	 Valley depth = -5.4 μm
Mean roundness	Peak count
 mean roundness = 1.9 μm	 Number of peak: 4

The machined roundness is influenced by number of factors which are unbalanced cutting forces, non integral headstock, lack of support on long work piece and type of insert shape used. During turning operation, a 200*mm* cylindrical stainless steel is used. However, only 50*mm* is utilized to clamp the workpiece at headstock. Considering this workpiece is not too long, the remaining 150*mm* is turned without supporting from tailstock at another end. Lack of tailstock supporting also influence workpiece roundness.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

By conducting experimentations and research on this project, the author enables to:

1. Conduct and analyze the experimental results of surface roughness when using CPO as cutting fluid in turning operation. The performance of CPO in improving surface roughness of workpiece is compared between dry cutting turning and turning with Solkut. The table below is showing the result of surface roughness.

   Table 5-1: Comparison of surface roughness at 10*mm* travelling length of stylus.

Surface Roughness	Condition during turning		
	Dry Cutting	**Solkut**	**CPO**
Mean Surface Roughness,Ra (μm)	3.53 – 7.86	3.13 – 7.33	2.78 – 6.92
Mean Roughness Depth,Rz (μm)	16.09 – 47.17	15.43 – 43.54	14.32 – 29.32

   The data above is showing the range of surface roughness at different conditions of turning. Based on the data above, turning with CPO resulted in lower surface roughness compare to dry cutting and Solkut.

   It can be concluded that CPO is better than Solkut in improving the surface roughness. CPO is suitable to be used as cutting fluid in turning of stainless steel. Machining other materials such as mild steel with CPO needs thorough consideration because CPO is acidic.

2. Investigate the effect of using CPO in turning on the roundness of workpiece. As shown in Figure 4.18, it is difficult to conclude the performance of CPO in improving roundness of workpiece because at some point of feed, it is better than Solkut but sometime it is not. For the example, at feed of 0.100 *mm/rev* to 0.200 *mm/rev*, the result of CPO is encouraging to prove that CPO can improve the roundness. However, for feed 0.236 *mm/rev* upward, the results are not as expected.

At this stage, the result shown by crude palm oil is still not sufficient to support it to be a suitable cutting fluid in turning. Further research must be carry out to verify whether CPO can be used as a cutting fluid in machining. However, their performances in turning are promising enough to encourage further development.

5.2 RECOMMENDATION

The author would like to suggest the varying of parameters in turning so that the performance of CPO could be monitor in larger scope. In this project, the author only varies the feed (*mm/rev*) in turning while cutting speed and depth of cut are kept constant. The author would like to suggest varying or manipulating cutting speed and depth of cut instead of feed. Based on research works, both of these parameters also give effect on surface roughness and roundness of workpiece. Varying the workpiece material also might be recommended. Instead of using stainless steel, mild steel and aluminum also can be used as workpiece in machining to determine the potential of CPO as cutting fluid.

Beside that, it is also recommended to vary the flow rate of cutting fluid during machining. As mention before, flooding is the method used to apply both cutting fluids: Solkut and CPO. In turning operation, flow rate of cutting fluid usually range from 10L/min [2]. By varying the flow rate, the author can observe the effect of flow rate on the quality of workpiece surface and roundness. Flow rate of cutting fluid also determine the pressure used by fluid to flush away the chips produced to prevent interfering with the operation.

Furthermore, repeatability of experimental work is one of factor to gain better results of the project. In this project, the author only repeated the testing for surface roughness and roundness but not for turning operation. This was due to cost and time restrictant. Thus, the author recommends to repeat the experiment for several times especially in turning operation as well as surface roughness testing and roundness testing. By doing that so more data can be generated and error analysis can be determined.

In addition, turning with CPO is very tough because of CPO easily to get viscous when its temperature goes down. Thus, for further study the author would like improve the performance of CPO by adding appropriate additives. Hopefully, by adding the additive the CPO would not easily get viscous at low temperature and could be used at any conditions. The additives also could help to reduce the acidic of CPO and adding the function of CPO as a coolant.

Moreover, applying CPO in turning need a proper flow system to make sure it is fully utilized as a cutting fluid. The author has experience in turning with CPO and realizes that it is important for CPO to have its own flowing system and do not mix with the current cutting fluid used by the lathe machine.

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APPENDICES

Appendix 3.1: General recommendation for Turning Operation [2]

TABLE 23.4 (*Continued*)

General Recommendations for Turning Operations

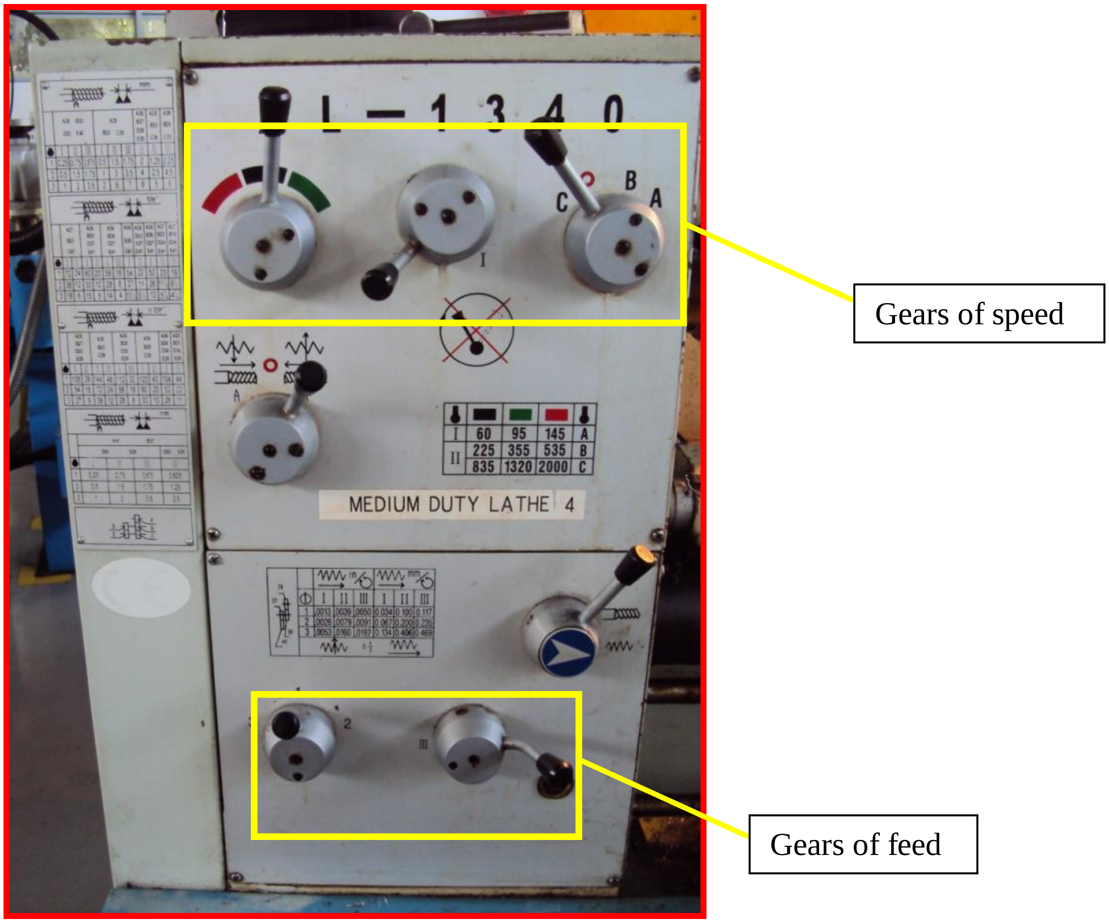
		General-purpose starting conditions			Range for roughing and finishing		
Stainless steel, austenitic	Triple-coated carbide	1.5–4.4	0.35	150	0.5–12.7	0.08–0.75	75–230
	TiN-coated carbide	"	"	85–160	"	"	55–200
	Cermet	"	0.30	185–215	"	"	105–290
High-temperature alloys, nickel based	Uncoated carbide	2.5	0.15	25–45	0.25–6.3	0.1–0.3	15–30
	Ceramic-coated carbide	"	"	45	"	"	20–60
	TiN-coated carbide	"	"	30–55	"	"	20–85
	Al_2O_3 ceramic	"	"	260	"	"	185–395
	SiN ceramic	"	"	215	"	"	90–215
	Polycrystalline cBN	"	"	150	"	"	120–185
Titanium alloys	Uncoated carbide	1.0–3.8	0.15	35–60	0.25–6.3	0.1–0.4	10–75
	TiN-coated carbide	"	"	30–60	"	"	10–100
Aluminum alloys							
Free machining	Uncoated carbide	1.5–5.0	0.45	490	0.25–8.8	0.08–0.62	200–670
	TiN-coated carbide	"	"	550	"	"	60–915
	Cermet	"	"	490	"	"	215–795
	Polycrystalline diamond	"	"	760	"	"	305–3050
High silicon	Polycrystalline diamond	"	"	530	"	"	365–915

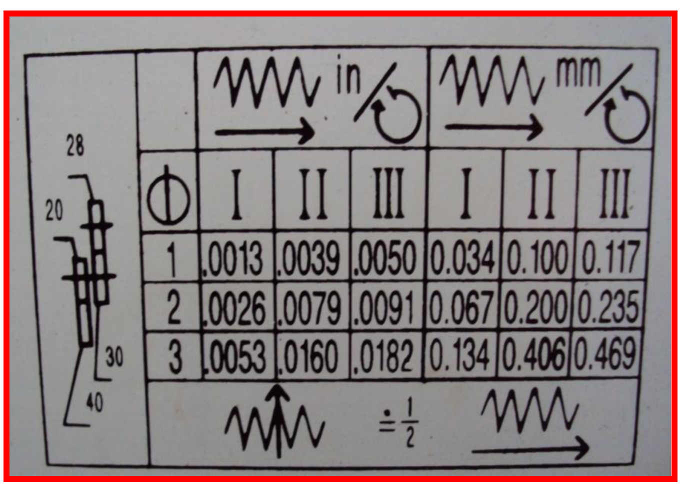
(*Continued*)

Appendix 3.2: The Procedure of Turning Operation

1. Before start using the machine, make sure the machine is in good condition and wear appropriated PPE for safety.
2. Turn ON main power supply located overhead of the machine.
3. Turn the power switch on the back of the machine to ON position.
4. The indicator light will turn on to state the machine in idle position.
5. Turn on illumination light switch and coolant supply switch.
6. Select spindle speeds for the machine and refer to the table in front of the machine for the correct speed and adjust the gear level to correct position.
7. To turn on the spindle clockwise direction, press down the gear lever down side. This will start the spindle and coolant pump motor. To turn spindle ant-clockwise rotation, pull the gear lever to upside direction.
8. To cut the work piece, slowly feed in the tool into the work piece by turning Z axis tool part to the left direction and X axis tool post to the clockwise rotation.
9. Maximum depth of cut on each cutting process is not more than 0.5*mm.*
10. Pull the gear lever to the center position to stop the spindle from rotating.
11. In case of emergency, press emergency stop pedal located underneath on the machine by feet to stop the spindle.
12. After turning is done, switch off the machine and housekeeping.

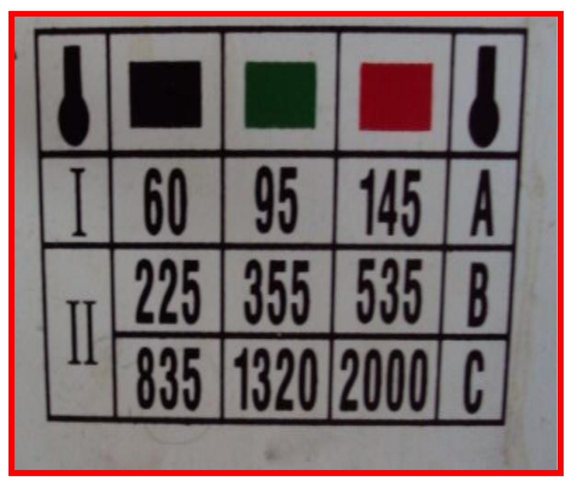
Appendix 3.3: Table for Variation of Speed and Feed.





	in/rev			mm/rev		
Φ	I	II	III	I	II	III
1	.0013	.0039	.0050	0.034	0.100	0.117
2	.0026	.0079	.0091	0.067	0.200	0.235
3	.0053	.0160	.0182	0.134	0.406	0.469

Table for feed



	Black	Green	Red	
I	60	95	145	A
II	225	355	535	B
	835	1320	2000	C

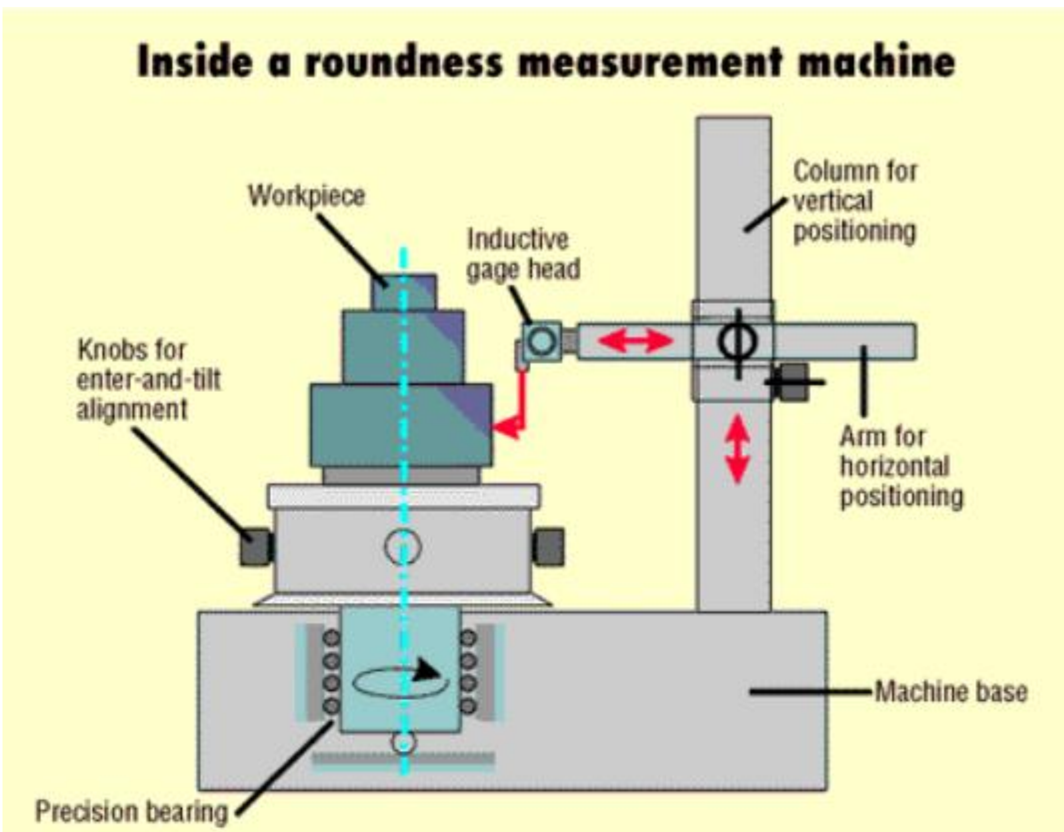
Table for speed

Appendix 3.4: The procedure of Surface Roughness Test

1. Check whether the dongle is connected to parallel port.
2. Check whether the drive unit or the the perthometer is connected to the computer.
3. If any of these connections has not been made switch of the computer, make the connection and with the computer back on again.
4. Switch on the computer and start windows.
5. Double click the CONCEPT icon program on the desktop.
6. Select ‘configuration of measure station’ dialog box will pop up.
7. Click ‘OK’ at the ‘configuration of measure station’ dialog box.
8. Go to FILE then OPEN FORM. Choose 3Ra measurement form.
9. To change the measurement setting, go to SETTING then ‘MEASURING CONDITION’.
10. Set the required measuring conditions and Confirm with OK.
11. Twist and Pull up the red button (ON)
12. Click the ‘Measurement Station View’.
13. Place the sample on the stage. Make sure the sample is under the stylus.
14. Press the down arrow button to lower the stylus. Stop before it touches the stylus.
15. Click the initialize icon.
16. Choose single or multiple measurements.
17. Click ‘Start Measurement’ icon then click ‘Close’.
18. The measurement will begin.
19. After the first measurement move the sample a bit so that the new surface can be measured.
20. Click the ‘Measurement View Station’ again and repeat the procedures.
21. When all measurements completed, click OFF the multiple measurement icon.
22. Double click on the Profile Info, go to Edit, Roughness Parameter confirmed with OK.
23. Click on the form to delete any extra form and Save the measurement under one file.

Appendix 3.5: The Procedure for Roundness Test

1. Turn on the Round-test Machine and air pressure valve.
2. Locate the workpiece on the spindle.
3. Press the [CENTERING] key to perform centering / leveling.
4. Press the [RNDNES] key to display the Roundness Measurement screen.
5. Set the stylus in the measurement position on a workpiece to be measured.
6. Adjust the detector position with the arm feed knob (coarse-feed) and jog dial (fine-feed) so that the stylus displacement is within the meter sensitivity range on the LCD.
7. Press [START] key to start the measurement.
8. Press the [RESULT] key to display the Result screen.
9. Press the [PRINT] key to print the results.



Rotating work piece type spindle

Appendix 3.6: Flow Chart of Palm Oil Processing at FELCRA Nasaruddin Factory.