UNIVERSITI TEKNIKAL MALAYSIA MELAKA

COMPARISON STUDY OF MACHINIBILITY PERFORMANCE BASED ON CNC AUTOMATED COOLANT SUPPLY SYSTEM

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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I hereby, declared this report entited "Comparison Study Of Machinibility Performance Based On CNC Automated Coolant Supply System" is the result of my research as cited in references.

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APPROVAL

This reported is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons) The member of the supervisory committee are as follow:

....
Encik Khairol Anuar Bin Rakiman

ABSTRACT

CNC machine is an industrial manufacturing machine that is used to improve quality and productivity of a product. There are two basis ways of applying coolant which are dry machining and wet cooling machining. Therefore, some researches had been done in order to obtain information about the method involved. It had been found that there are disadvantages to both techniques and this had affected to the workpiece, tooling, health and also environment. Moreover, the used of wet cooling technique causes waste and increasing productivity cost. This is because only 10% to 15% of coolants is able to play their role when it is supplied to the tool and workpiece to decrease the temperature, and the other percents of coolant is not be used. Hence, the idea of using PLC that inspired the control system of coolant supply plays the main role in developing the modern technology and industry. The purpose of this project is to develop the time-based coolant supply system and to test the performance of the machining through the surface roughness of the workpiece. The structure of this project involved development in software and hardware. The adjusted device to control the coolant supply is used by applying a washing machine inlet control valve. Next, the used of PLC is to open and close the valve. The experiment started by testing the performance which are tool speed, depth of cut and feed rate of the machine with unloaded coolants by using 5s interval time to confirm the functionality of the system. Then, it is tested with flooded coolant with combination of parameters. Lastly, 8 interval times are used to run Experiment 2 and Experiment 3. The performance of each time interval between 2s to 25s of coolants supply is analysed in term of the surface roughness of workpiece and tool wear. Average data of the analysis setup is then obtained to plot the graph in order to get the best interval time in term of surface roughness with optimum conditon of speed, depth of cut and feed rate.

ABSTRAK

Mesin CNC merupakan industri mesin pembuatan yang digunakan untuk meningkatkan kualiti dan produktiviti sesuatu produk. Terdapat dua cara biasa untuk mengaplikasikan sistem penyejukan ini iaitu melalui teknik pemesinan kering dan pemesinan basah. Oleh itu, beberapa kajian telah dilakukan untuk mendapatkan maklumat mengenai beberapa kaedah yang terlibat. Dalam kajian ini, didapati bahawa terdapat kelemahan untuk kedua-dua teknik tersebut memberi kesan terhadap bahan kerja, peralatan yang digunakan, kesihatan, serta alam sekitar. Selain itu, penggunaan teknik pemesinan basah akan menyebabkan pembaziran dan meningkatkan kos pengeluaran. Ini kerana, hanya 10% kepada 15% cecair sahaja yang memainkan peranan mereka untuk mengurangkan suhu mata alat serta bahan kerja. Oleh yang demikian, idea penggunakan PLC untuk menggantikan penyejuk manual kepada automatik telah diilhamkan sebagai sistem kawalan dan ianya amat memainkan peranan didalam sektor pembangunkan industri dan teknologi moden. Tujuan utama projek ini adalah untuk membina sistem penyejukan berasaskan masa dan untuk menguji prestasi mesin melalui kekasaran permukaan bahan kerja. Selain itu, struktur projek ini melibatkan penyediaan 'software' dan 'hardware'. Masa diselaras untuk mengawal pengeluaran cecair bagi menyejukkan bahan kerja serta mata alat. Ia dikawal menggunakan inlet mesin basuh. Seterusnya, PLC digunakan bertujuan untuk membuka dan menutup injap. Eksperimen ini dimulakan dengan menguji prestasi mesin dengan menggunakan kelajuan, kedalaman pemotongan serta kadar suapan. Kemudian, eksperimen diteruskan dengan penggunaan cecair melalui beberapa jenis penggabungan 'parameter'. Akhir sekali, 8 masa yang berbeza telah digunakan untuk menjalankan Eksperimen 2 and Eksperimen 3. Prestasi untuk setiap masa daripada 2s kepada 25s yang digunakan dianalisa dari segi kekasaran permukaan dan penggunaan alat. Purata data setup analisis kemudiannya diperolehi dengan memplot graf bagi mendapatkan selang masa yang terbaik untuk memperoleh keadaan optimum bagi kelajuan, kadar suapan (feed rate) dan kedalaman pemotongan.

DEDICATION

This report is dedicated to my beloved parents, Wan Md Hatta Bin Wan Ahmad and Marini Binti Wan Ibrahim as well as my caring and supportive family members who has always stood by my side in facing the circumstances. Besides, a highest gratitude to my project Supervisor, Encik Khairol Anuar Bin Rakiman, lecturers and friends that always give me a useful guidance and show me the correct paths from the beginning to the end of the project.

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Last but not least, I would like to thanks everybody who was actively helped me throughout the whole project and also expressing my apology regarding my shortness and mistakes.

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LIST OF ABBREVIATIONS

CNC	-	Computer Numerical Control
NC	-	Numerical Control
PLC	-	Programmable Logic Control
MQL	-	Minimal Quantity Lubrication
AL	-	Aluminium
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
G-code	-	Preparatory Code
LED	-	Light Emitted Diode
USB	-	Universal Serial Bus
PC	-	Personal Computer
AC	-	Alternating Current
DC	-	Direct Current
CPU	-	Central Processing Unit
2D-2	-	Dimensional
I/0	-	Input and output
ECU	-	Engine Control Unit
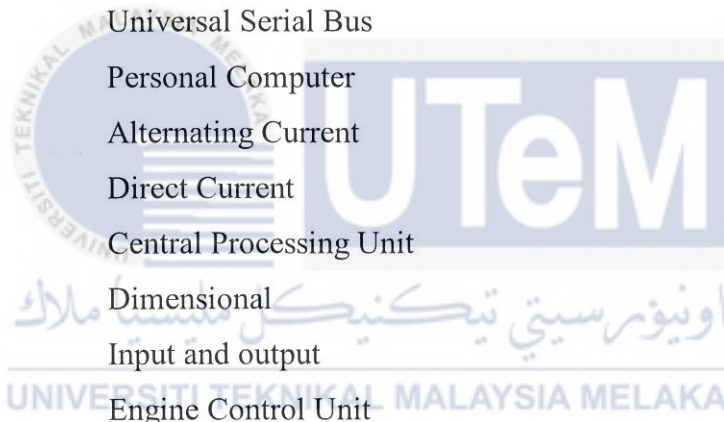
LIST OF SYMBOLS

%	-	Percent
Mpa	-	Mega Pascal
M/min	-	Meter per minute
Mm	-	Milimeter
mm/rev	-	Milimeter per Revolution
rpm	-	Revolution per Minute
μm	-	Micrometer
ml	-	Mililiter
s	-	Second

CHAPTER 1

INTRODUCTION

The overview of this chapter explains about Computer Numerical Control (CNC) machine, the cleaner application software and a method to be applied in the coolants system. Next, the used of PLC is explained in order to replace the conventional method. After that, the problem statement, objectives and scopes are discussed.

1.1 Background

Development of Computer Numerically Controlled (CNC) machine is a tremendous contribution to the manufacturing industries (Ansar *et al*., 2016). The programmable language which is controlled by the new CNC machines had an ability to carry out a wider variety of tasks with greater accuracy. The performance of the machines allowed high automated control, which can improve the productivity of the product. There are a few technologies used in metal cutting machine (CNC machine) for example milling, lathe and turning machine. Ansar *et al*., (2016) stated again that to increase the flexibility of the machine in handling a variety of components and to finish them in a single set-up on the same machine, CNC concept was applied to develop a CNC machining centre for machining prismatic components combining operations for example milling, drilling, boring and tapping. Therefore, the process with high machining speed, small amount of feed rate and large depth of cut can generate heat in profusion and increase the cutting temperature in machining.

The increasing of heat due to friction and energy lost can lead the cutter to be unsharpened and it will affect high power usage and poor in surface finishing. In other hands, the poor coolant cause of the low thermals conductivity in air surrounding. According to

Dhar & Kamruzzaman (2007) the increasing of temperature induces accelerated tool wear and deteriorates the surface quality . Then, it was supported by Mia and Dhar (2015) that it will reduce tool wear, prolonged tool life, improved surface finish and integrity of the lessened cutting temperature when the coolant is used. Thus, the coolant system is necessary as a safeguard to a system from overheating and to remove excess heat at the workpieces. It is needed to get the desired size control and shape of the workpiece. The most function of the coolant system is to cool and to lubricate machines and cutting tools.

Generally, the common coolant types that are used in manufacturing are cutting oils and cutting fluid. The interface between tool's cutting edge and the chip at the cutting stage are prevented using the cutting fluid which is also fluid that is used in the coolant system at CNC machine. This heat was prevented by preventing friction at this interface. It was stated by Courbon *et al.* (2009) that the accredited of favourable thermos-mechanical interaction crafted by the acted coolant for the foregoing benefits. Later than, it was clearly explained by Mia and Dhar (2015) that these benefits are diminished by environmental degradation and poor health condition of human operator triggered of the environmentally in-compatible coolant. In heat generated 80% of it was carried by chips while other 20% use coolant to take away.

Coolant 20 %

Chips 80 %
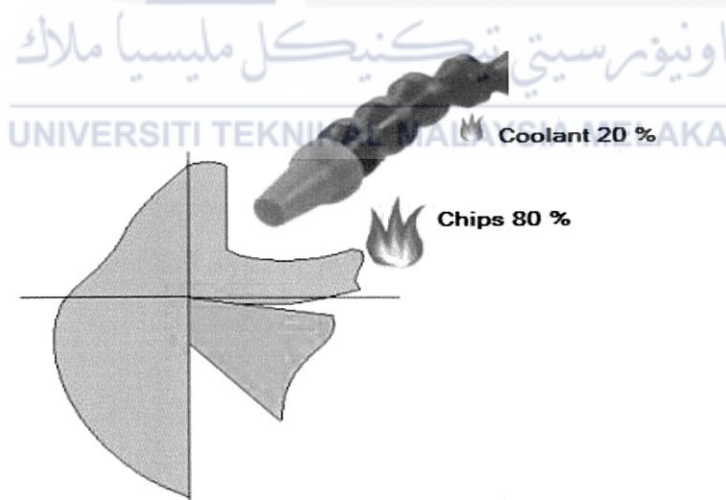
Figure 1.1: Percentage of the heat generated (Source:
http://cadem.com/cncetc/cnc-machining-coolant/

Next, the serious issues about health, environment and economy had been affected by the use of coolant fluids. Therefore, a few methods need to be obtained to investigate this problem. To investigate the problems, minimal quantity lubrication (MQL) is used

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regarding the surface roughness, tool wear, temperature deviation, depth of cut and the amount of the coolant system used. The process of applying minute amounts of high-quality lubricant directly to the cutting tool or workpiece is call as MQL. According to a study of Unist (2012) stated that, Ford saw a 13% decrease in overall cost after the implementation of MQL. After that, it was stated again that this decrease in costs was due to better cutting tool life, a significant fluid reduction, reduced costs of coolant handling, decrease maintenance and an increase of machine uptime. Moreover, MQL minimizes environmental impact by reducing fluid usage and decreasing the need for coolant treatment and disposal.
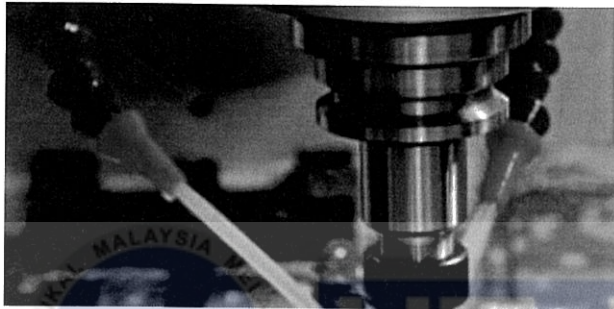
Figure 1.2: Coolant system (Source: http://cadem.com/cncetc/cnc-machining-coolant/)

With the details concepts of MQL application, it has sparked the idea in this research work because the application of MQL refers to a small amount of cutting fluid with the form of mist rather than flooding the workpiece. This option can reduce waste and minimize the production cost. The aim of this project is to program Programmable Logic Controller for an automated coolant supply system in CNC turning machine as well as to analyse the performance of automated coolant system in CNC turning machine in term of surface roughness and tool wear.

1.2   Motivation

This project is an inspiration to improve the wet cooling technique. The wet cooling technique has been widely used in the past with an application of a stable flow of the coolant to the tool and workpiece. It is clearly seen that this system produced a lot of waste when large amount of fluid being projected to the workpiece. In addition, it only needs a small amount of the coolant to cool down the temperature of the tool and workpiece. Moreover,

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continuous flow of the coolant causes the increase in production cost because the coolant has to undergo recycle frequency in 2 to 3 weeks' time. Due to the particular disadvantages, the student research had been done before using the idea of MQL method with the help of PLC. The time-based coolant supply was built to increase the recycle lengthen of the coolant while it will reduce the cost. Hence, continuous research need to be implemented to study the interval time that give the best value of the surface roughness.

1.3   Problem Statement

Basically, the conventional of CNC machines use a wet cooling method to reduce the heat and excess chips at the workpiece. However, in this study there are three major problems that exist when the wet cooling method is apply. Firstly, the production cost increase due to the continuous flow of the coolant in the system. This causes the shorten time for the coolant to be recycled. Then, a large amount of fluid is being projected to the workpiece and this produces a lot of waste since they only need a small amount of the coolant. Moreover, the use of excessive coolant in an extended period can affect health and environment. The increasing of heat due to friction and energy lost can lead the cutter to be unsharpened and it will affect high power usage and poor in surface finishing. Therefore, MQL method and the development of PLC to control time-based coolant supply is used to minimize the problems.

1.4   Objective

The objective of this project:

i.   To program Programmable Logic Controller for an automated coolant supply system in CNC turning machine.

ii.   To analyse the performance of automated coolant system in CNC turning machine in term of surface roughness and tool wear.

1.5 Scope

The scope of this project:

i. Using Haas SL-20 CNC turning machine.

ii. Using Omron CP1E to program the PLC.

iii. CNC Laboratory room as a workplace to do the experiments.

iv. Workpiece will be AISI 304L only, other types of workpiece material will not be considered.

v. The cutting fluid used is Al Soluble Extra and other types of cutting fluid will not be considered.

1.6 Report Structure

There are five chapters that covered the report structure including introduction, literature review, methodology, result and analysis. The first chapter is chapter 1 that explained about the introduction for the whole project. A background of the project, the motivation, objectives, problem statement and scope of this project had been covered. Chapter 1 had been seen importance since it is needed to give a brief idea for the other chapters.

Next, chapter 2, Literature Review is displayed about the past study from a lot of resources such as journals, articles, books and internet that supports the topic of this research project. A few techniques to apply coolants are explained in this chapter. Moreover, the idea to use PLC and their benefits will be discussed.

Chapter 3, Methodology explained detailed about the techniques and method used to collect data. Then, a flow chart is constructs to conduct the overall flow of this project to get

an idea for the working flow progress. The procedure in building PLC controlled in the automated coolant system is explained clearly by studying the ladder logic and ladder diagram.

Chapter 4, Result and Analysis involve the development of hardware and software. Then, the collection of data will be analysed and utilised. The best interval time need to be evaluate in term of surface roughness and tool wear. The average value of the result gain form the experiments are calculated and the graph are plot.

Chapter 5 concludes the objectives of this research project. The results obtained from the data and analysis will show the performance of the machine and the achievements of this research project. Also, the recommendations for future works to increase the machinability are suggested.

CHAPTER 2
LITERATURE REVIEW

In this chapter, there will be a brief explanation of the related topic of this research project. History of CNC machine, differences method to apply coolant and importance of using control system as an option to replace the conventional method are described. The evidence that comes from the problems statements are supports by the literature review that will be explained in the following below.

2.1   Computer Numerical Control (CNC) Machine

Nowadays, one of the most modern intelligent system and machining technologies that easy to handle a device and can perform multiple machining tasks is Computer Numerical Control (CNC) Machine (Ambrizal *et al.* 2017). It is produced based on the basic concept of Numerical Control, NC which is started with the idea of automation tooling in machinery system that then fulfils the requirement of the ideas in programming logic. Ansar *et al.* (2016) stated that the development of NC machine tools has allowed the designer to shed some of his chain, which inhabited him while using conventional machines. The control of this machine followed certain points and was design based on manufacturing tools machines and motors for the movement. After that, the advanced computer technology had built the computer numerical control. Example of CNC machine frame is shown in Figure 2.1.
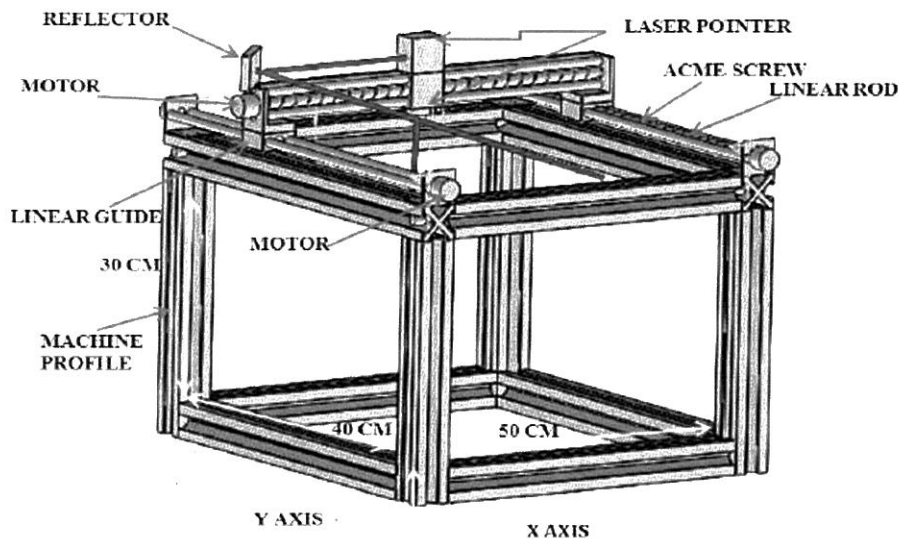
Figure 2.1: Isometric view of CNC machine frame (Source: Ambrizal *et al.*, 2017)

CNC machine consists of a microcomputer that performs controller unit of the machine. The functions of the computer are to control, automate as well as monitoring the movement of the machine axes, workpiece and tool. With the works of drive components and a few motors, CNC machine controller can be used to drive directly to the motion of machine axes and calculated the programming motion in the system. Ambrizal *et al.* (2017) claimed that the system is built to allow users to perform the motion of tools and parts through numerical data. CNC machine performance can be reached using differences parameter including tool wear, surface roughness and chips formation. Some advantages of the CNC machine are:

- High precision and accuracy

- Good manufacturing flexibility

- Non-stop working hours

- Minimized human errors

Some of the machine tools that run on CNC machine are milling, lathe and drilling machine while the purpose of using this machine is to remove excess metal in order to get a perfect shape. According to Chiu and Lee (2017) the indicators or product quality of milling

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accuracy and surface quality are depending on CAD/CAM, machining parameter of CNC controller, servo loop, and feed drive system. These drivers usually based on the configuration of parameter which holds data of the machine stiffness, input command and control velocity and position for parameters of the servomotor (Hidalgo *et al.*, 2017). The machining flow, shown in Figure 2.2, includes design of CAD/CAM, machining parameter of CNC controller, servo motor, feed drive system and mechanical property.
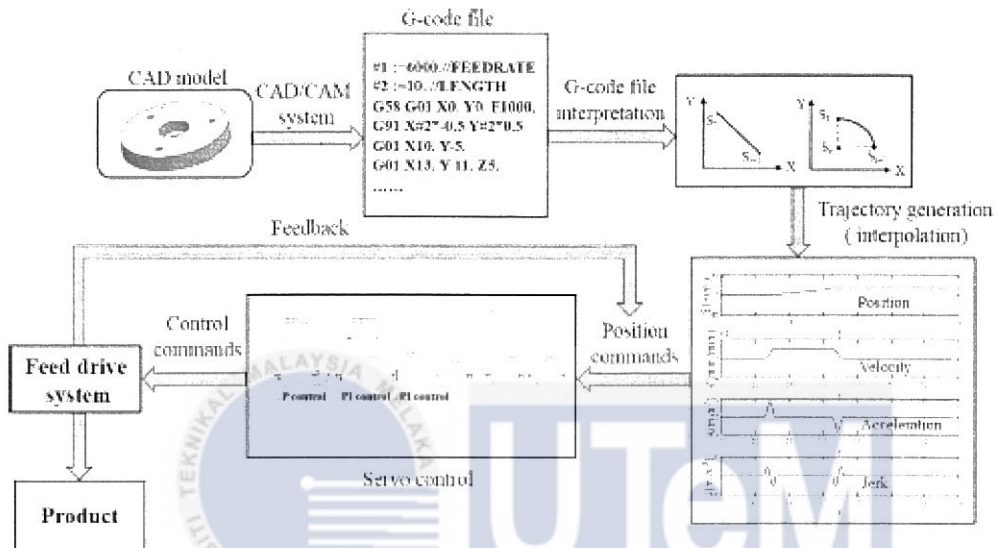
Figure 2.2: Illustration of machining flow (Resource: Chiu & Lee, 2017)

Next, both combination of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) deals along with the technologies which increase the speed of design, creation and manufacturing process. The purpose of CAM software is used to command tools for machining and manufacturing workpiece while CAD software that produces toolpath have an ability to move machine tools into parts. According to Shchurov (2015), the development of CNC program is built by applying CAM system and the modern system of CAM that used to generate CNC program does not require cutting angles for the fibre composites. Therefore, to compute the overall system of CNC machine, special characters are used as programming languages to the system which is known as G-code.

G-code is language that connects people with a machine by giving an instruction to the machine controller that will construct motion of the system. This languages code points to point coordinated programming languages to control the direction of x, y and z for examples to give a rapid movement, linear interpolation, clockwise or counter clockwise in

CNC machines system (Ambrizal *et al.*, 2017). It was supported by Tajima and Sencer (2017) that G01 is a tool-paths for a short linear segment to give a movement and most of it usually used to discrete path using short linear segment and other code for pre-specified curve and a spline are used in NC system to change the feed direction within machine kinematic for the achievable accuracy and speed of CNC.

Therefore, a task with high repetitive, high accuracy and precision will produce high-quality product. This produces heat and excess cutting zone because of friction happened between the workpiece and the cutter and the overheating of the tooling will be result of decreasing the productivity. To achieve environmental sustainability in the manufacturing industry, use of cutting fluid is needed since it caused industry and academia to re-examine the role of this fluid and amount their benefits and this problem can be reduced by applying the fluid at the cutting zone (Elahi *et al.*, 2015). In other hands, cutting fluid is currently important in performing the CNC machining process. A few types of different coolant supply method are investigated to find the best coolant system in order to increase the productivity and decrease the heat generation.

2.2 Coolant Supply System

The increasing of temperature due to friction and energy lost can lead the cutter to be unsharpened and it will affect high power usage and poor in surface finishing. Based on Sartori *et al.* (2017) which stated that cutting fluid disposal, components cleaning, pollution and human health damage are a few problems that affect toward more stringent regulation in order to encourage the use of innovative environment-friendly technologies. This supply coolant system is needed to get the desired size control and shape of the workpiece. The most function of coolant system pump is to cool and lubricate machines and cutting tools. When a cutting fluid supplied lubrication to a machining process, it serves to decrease friction levels and thus stable the increases in temperature (Tawakoli *et al.*, 2009). Figure 2.3 shows the area of heat generation due to friction in the cutting zone.
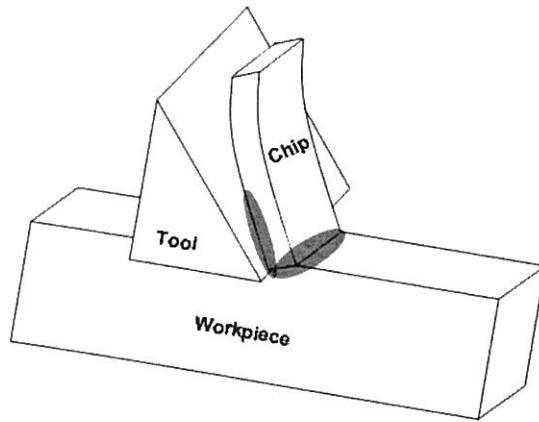
Figure 2.3: Area of heat generation due to friction in the cutting zone
(Resource: Elahi *et al.*, 2015)

Moreover, according to Mia and Dhar (2015), for effective cooling, a high transfer rate is required and one way to achieving is impingement of multiple pressurized jets. In addition, a few techniques had been discussed to overcome the heat problem issues. Each coolant techniques have differences characteristics due to the designated and manufactured to suit industrial specification. Niaki and Mears (2017) claimed that from different perspectives, the efficiency of machining operation can be studied. Therefore, it needs to be clearly understood in term of advantages and disadvantages before using that technique.

2.2.1 Dry Cooling Techniques

Dry machining represents a system without a coolant applied on the workpiece to cool down the tool during the machining process. This is widely used in industry as a technology for removing heat from the workpiece as to much heat will affect the surface roughness of the final product. The best reason to use this method are good for health and clean environment due to unpresent of fluid. Dry machining rapid tool wear was recorded when coolants are avoided but it is an environmentally friendly machining process with absence of hazard cutting fluid. According to Sreejith and Ngoi (2000), the machining without the use of any cutting fluid (dry or green machining) is becoming increasingly more popular due to concern regarding the safety of the environment. This is due to the advantages of the dry machining system;

- Clean work environment

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- No fluid emission to the environment

- No thermal shock at the cutting tool

- Lower manufacturing cost

- Reduce undesirable influence to the atmosphere

However, problems such as overheating usually occurs. Since they will be subjected to higher temperatures, there will be more presents of friction and adhesion between the tools and the workpiece in dry machining (Sreejith & Ngoi, 2000). Overheating at the cutting edge can reduce the tool life and effect in the poor surface finish. Also, the effect of the surface finish occurs because of high friction in dry machining and this lead to built of edge formation and high tool wear. It is according to Sreejith (2008) that this high temperature at the machining zone will ultimately cause dimension accuracies for the workpiece and tool wear problems. In order to stabilise great surface finish, feed rate and speed need to be slow down and adjustable. In this condition, the productivity decrease and production cost had risen due to the adjustable of the speed and feed rate. In figure 2.4 shows the example of dry machining.
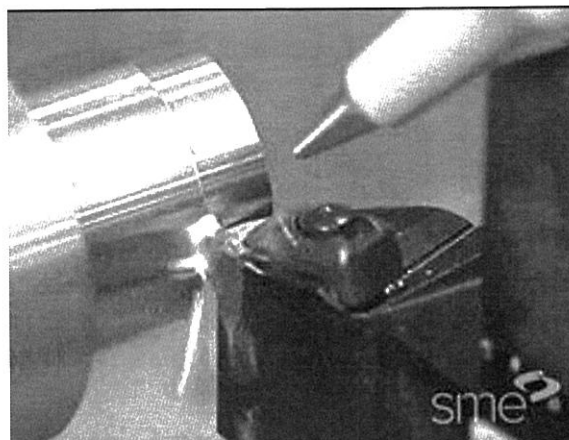
Figure 2.4: Dry machining (Resource:
https://gfycat.com/gifs/detail/DigitalAccurateFeline)

Therefore, a lot of research had been conducted to solve these dry machining problems. It was according to Braga *et al.* (2002) to reach this goal, it is necessary to find the suitable cutting conditions and also to develop new tool material with lower friction coefficient and high heat resistance. The experiment is carried out using coated carbide inserts in the process of steel turning. The improvement in the coatings of carbide tools and in the chemical and mechanical properties of tool materials has caused the increase of tool working life in machining process (Braga *et al.*, 2002). From the result, it produces smaller surface roughness. Klocke and Eisenblätter (1997) stated that it is also necessary to increase the tool nose radius in order to keep the surface roughness at the same level. This is due to the effect of temperature dry cutting at the workpiece which is close to the cutting region and it declining the strength and hardness of the work material.

Moreover, the designated of tools can be sharper and unsharperned depends on the performance of the machine, speed rate and feed. The sharper drill can reduce the change of the tool from the softer to harder effect on reducing the tool life because the harder material can cause the edge retain a high cutting temperature difference from softer tool that prevents it from being too brittle. Both deformation and cratering can be specified and decrease tool life in dry applications using the harder grade of carbide. However, the application of such tools can only a lower order of cutting speeds, the limitation is due to the cutting temperature (Sreejith & Ngoi, 2000). When that happens, its needed to use larger tool radius or the milling equivalents to keep the finish up.

2.2.2   Wet Cooling Techniques

Wet coolant technique is one of the methods to cool down the temperature which also have two functions in both cooling and lubrication process. This machine is commonly used in machining operation industry such as CNC machine. Fazle Elahi *et al.* (2015) claimed that the tool wear and machine surface quality can be improved with the application of wet coolant technique. With this, unpresence friction that occurs between the tools and surfaces can be removed using the right tool. This is because the increasing of temperature at the cutting zone and workpiece during machining process may affect the surface roughness of the product that were produced.

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Moreover, the differences temperature causes extreme heat for the plastic deformation on the cutting edge during the process and this leads to thermal cracks. The situation above affect high heat generation for milling conditions for examples machining difficult-to-cut materials or making rough passes with significant machining allowance. According to Sreejith (2008), this method can be used to lubricate metal forming and it obtains environment harm and potential damage in term of chemical constituents in the machining. Example of wet coolant technique is shown in Figure 2.5.
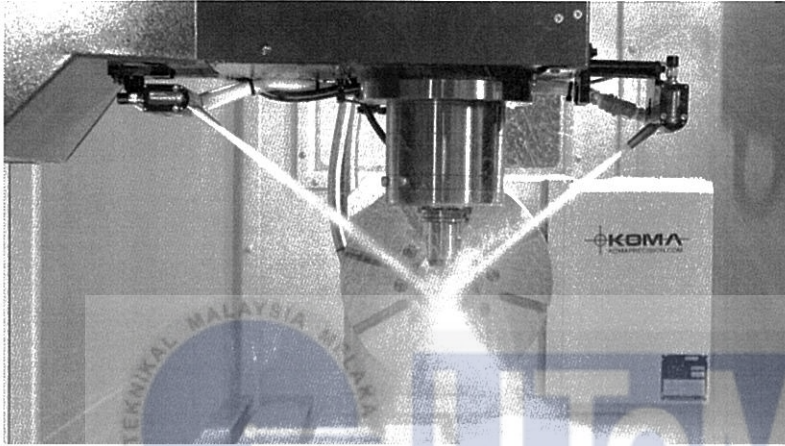
Figure 2.5: Wet coolant technique (Source: http://spidercool.com/)

2.2.3 Mist Cooling Technique

A spray mist coolant system method which sprays a fine volume of coolants to lower the heat and lubricate of the cutter and workpiece. This work happened by forcing accurate high-speed air stream through a designed nozzle and as a result it will produce a several inches fine spray pattern to the target. The system used extremely low coolant supplied which is 30 ml/h while some of it is also influents by the type of the machine used. Therefore, a small amount of coolant that eliminate excess heat is used to remove coolant waste and save cost. A mist of coolant is supplied intermittently by the researchers in order to get the goal pulsed jet cooling (Fazle Elahi *et al.*, 2015). Meanwhile, Elwekeel and Abdala (2016) claimed that at lower mist temperature that is gained by the coolant can be improved with mist addition to the stream. This technique is widely used because it provided a good and functional coolant. Figure 2.6 shows the example of dry machining.
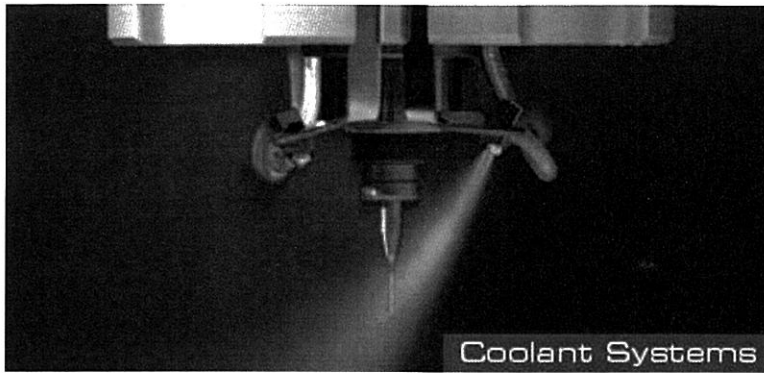
Figure 2.6: Mist coolant technique (Resource:
https://www.datron.com/accessories/coolant-systems.php)

Coolants are necessary for the machining of material, for example, aluminium alloys and mostly used stainless steel, which leads to adhere to the tool and affect a built-up edge (Sreejith & Ngoi, 2000). Figure 2.6 shows the examples of mist coolant technique. This type of method is better because the presence of the coolant does not break into a small mist and it will not release to the atmosphere. According to Sreejith and Ngoi (2000) again, by using mist lubrication the consumption of the cutting fluids has been decreased. Therefore, the specified amount of the coolant being used on the workpiece, the greater the cooling and lubrication that obtain along with decreasing coolant waste.

2.2.4 Minimal Quantity Lubrication Techniques (MQL)

According to Unist (2012), minimal quantity control (MQL) is a process that applied a small amount of quality lubricant into the cutting tool-workpiece interface and this method commonly effective in a differences metal cutting process such turning, milling, drilling and tapping. The coolant can deliver into two conditions which are with air and without air in aerosol system. The minimal quantity lubrication (MQL) can be applied instead of dry machining (Sreejith, 2008). This technique is a mix of conventional lubrication of cooling and dry machine which a small amount of oil will be combined with compressed air flow to the workpiece interface. To meet the requirement, MQL technique had widely used in industry to get the accurate result and been used in machining process using tool to define their geometry. The example of MQL shows in figure 2.7 Figure 2.8 below.

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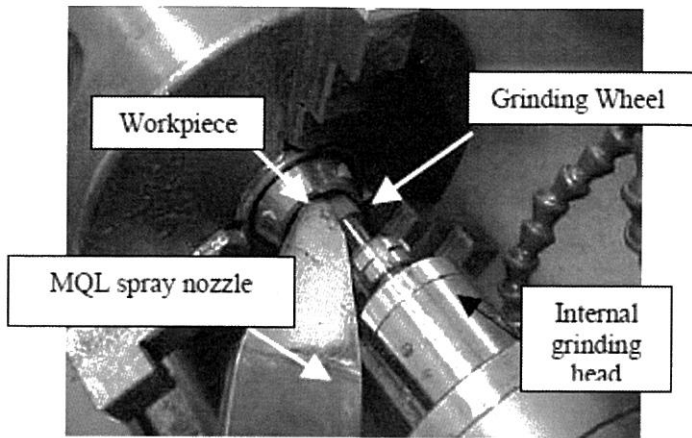
Figure 2.7: Position of MQL spray nozzle in the cutting region (Resource:
http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-58782009000100001
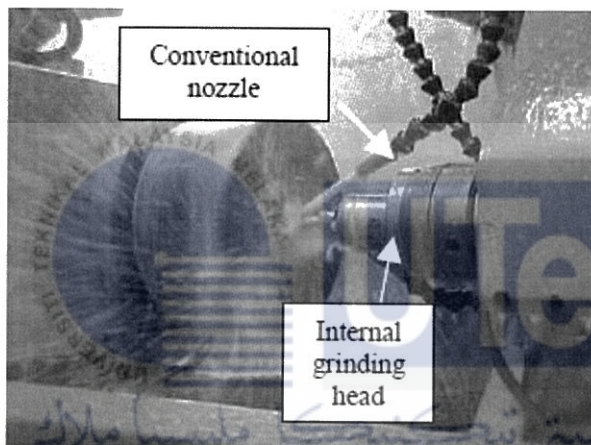
Figure 2.8: Conventional coolant system under operation (Resource:
http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-58782009000100001

In addition, the specified amount of 5 to 50 ml/min of fluids is applied to the cutter and workpiece which also depends on the performance of the machine and the type of the workpiece used. Besides, it fulfils the Braga *et al.* (2002) statement that the goal of MQL technique is to minimize the amount of cutting fluid applied in the machining process. According to Unist (2012) to gain the successful implementation of MQL, the presence of lubricant is needed between the cutting edge and the workpiece. Otherwise, the reduction of coolant systems causes significant saving from energy and equipment. Then reduce the flexibility to replace the machine, minimizing the waste stream, minimize the floor space to get clean and healthier work environment (Tai *et al.*, 2014). It was supported by Sreejith (2008) that the cutting fluid of MQL not only selected based on the characteristic of cutting performance but also biodegradability, oxidation stability, and storage stability.

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Furthermore, the action for maintaining the thermal stability need to be taken as part tolerance to minimize the amount of heat in order to reduce thermal grow at the tool and workpiece. Differences from other technique, MQL in a rough machining is used to reduces essential unrequired parts. With a tight position of bearing bores and dowel holes causes the process to be finished earlier. This situation will not be affected by the thermal aggregation and the example of the operation are drilling and tapping. Besides, it provides a cleaner, greener alternative to classic fluid supply in embracing sustainability initiatives and implement capabilities. It showed a good lubrication performance during the same cutting condition in MQL used water droplet (Sreejith, 2008).

In other hands, a specified number of implementation in MQL need an appropriate designated machine tool. For example by allowing the same feed rates and speed that are used in wet coolant process. With the increasing of feed and decreasing of cutting speed, the same amount of heat are generated but the area of tool that gains the heat is bigger which causes the lower in temperature and constant in the amount of chip remove per minute without increasing the cutting time (Braga *et al.*, 2002). According to Tai *et al.* (2014), the fundamental research in milling, turning and drilling had proved that MQL can perform the same or even better than the wet condition in medium range in the processes of cutting for examples such as in milling and shallow drilling on aluminium. The cost by using two system had been shown in the result on Figure 2.9.
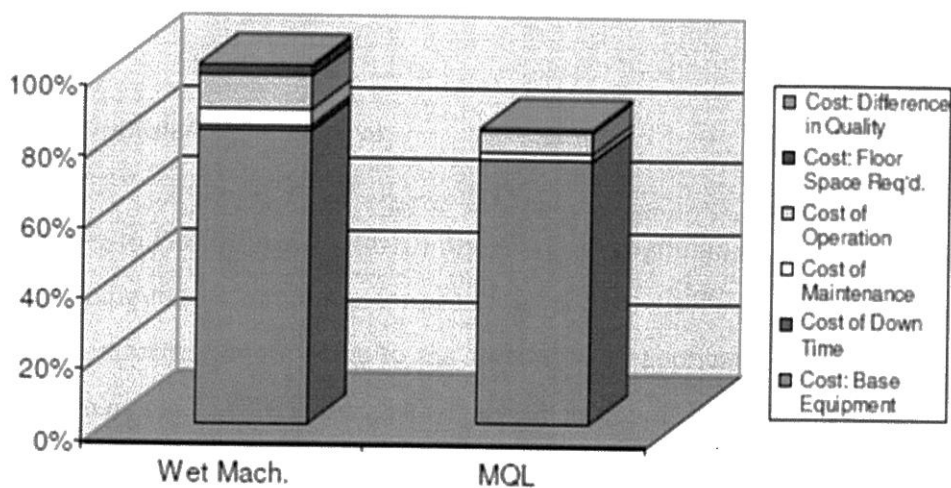
Figure 2.9: Life Cycle Analysis of wet vs. MQL machining for specific transmission part (Source: Furness R *et al.*, 2006).

Machining with MQL is generally viewed as low emission process due to the decreasing of metal working fluid (MWF) reveal in the inhaled air or in the skin difference to the wet machining (Tai *et al*., 2014). After that, (Tai *et al*., 2014) stated again that the development of MQL needs manual adjustment to accommodate different tools to obtain oil coverage at the cutting edge (Tai *et al*., 2014). Besides, as long as the mixing and dispersion of oil are precisely controlled, part quality is good or better than wet machining processes. In the final analysis, MQL machining provides an economically and ecologically reasonable alternative to the traditional wet machining process.

2.3   Automated Supply System

Nowadays, industrial with an automated machine is usually used in the market and manufacturing industries. Therefore, to relate with the aim of the research project the controller of CNC coolant supply machine is needed in order to achieve an eco-green and economic beneficial machining industries. This is due to the extensive use of cutting fluids in machining operations leads to a sizeable waste stream (Fazle Elahi *et al*., 2015). The amount volume of coolants that supplied to decrease the temperature of tool wear and workpiece as well as the time interval needs to be controlled to reduce waste and production cost. Hence, a previous research on PLC controller is taken as an evidence for the sustainability of this controller to control the coolants that will be supplied to the workpiece.

2.3.1   Programmable Logic Control

According to Dumitru *et al*. (2010), the used of Programmable Logic Controller are to connect the computer with monitor for each load and electricity consuming device and it usually used in industrial control due to the flexibility in applications and easy to install. Supported by Quan and Li (2011) that the achievement of soft PLC can be divided into two parts which are development system and running system and it is used as a core of the soft PLC, executes the program and to process the input and output. Moreover, in this high civilization, the demand for automation is highly needed in the industry as the human core. Therefore, relays are used to replace and control the system that energize the starter and also

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to turn switch of the motor voltage as the PLC controls the relay. Some benefits of PLC are stated below:

- Flexible and easy to learn for a beginner.

- Interfacing of input and output that already inside the controller.

- Rugged and were designed to resist vibrations, temperature, humidity and noise.

- Able to solve all the logic in the repeating sequence and in an expectable.

- Easy to understand the programming language.

- Able to enhance the productivity and product quality.

Furthermore, it was claimed by Ergenc and Koca (2014) that PLC has real-time operating systems, timers and counter crucial for real-time control systems and relatively control application for economical resolutions. This control system plays the main role in developing and advance the modern technology and industry due to the demand numbers of product to be produced. In the recent study by J.h. Al Gizi *et al.* (2015) stated that the modelling and simulation of the control system became multifaceted and the major challenges in the compound system are the extreme nonlinearities and the interaction between the control loops which then make the modelling difficult. Iovev and Yakimov (2015) stated that PLC as a gateway of circuitry that was used to interconnect networks to converting the protocol of each network to others.

Therefore, it is suitable for this project due to manual operation and the used of time bases concept in controlling the coolant that will be supplied in order to reduce the temperature. The differences timer will be used in controlling the coolant. According to Ergenc and Koca (2014), there are precision timers for injection timing, high-speed counters for counting incremental encoder pulses to get crankshaft position and also high speed pulse generators for injection signals and the used of PLC as an ECU that collects data from

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sensors such as crankshaft encoder, pressure and temperature transducers. After that, it will be generated by driving signal of the injectors.

2.4   Summary

In this chapter, a brief research about the Computer Numerical Control (CNC) machine, the cleaner application software, a method to be applied in coolants system and the automated system had been discussed to get the best method that will be used in order to achieve the objective. It had been through along the past research from the sources such as journals, articles, books and internet. This research had been combined to get a new solution for the problem that will be analysed. The identification of related topics is used as other references in order to get information about the projects. Therefore, literature review had been seen important as it is grounded as potential support that will bring to future work and as a tool in solving the problems.

CHAPTER 3

METHODOLOGY

In this chapter, a methodology is performed with a set of procedures, information, rules and techniques. This methodology is used to fulfil overall method of the project and it is constructed with a particular branch of knowledge. For a beginning, a short discussion had been done in order to discuss the project title. The plan requires a branch collection of strategy to get the proper outcomes. Then, the detailed about the techniques and method used to collect data are explained briefly. The procedure in building PLC controlled in automated coolant system is explained clearly by studying the ladder logic and ladder diagram. Lastly, the performance of machine tools and the material is very consequent for machining capabilities to gain a better result.

3.1 Introduction

This report is to program Programmable Logic Controller for an automated coolant supply system in CNC turning machine as well as to analyse the performance of automated coolant system in CNC turning machine in term of surface roughness and tool wear. To achieve this goal, a precise research had been done to complete this project. The data from journals, articles and books about PLC controller and CNC Coolant System had been collected. Also, other resources such as internet had been used as an additional listed for some information that may be left behind. Some of the procedures are constructed in a flowchart which are necessary to get an idea of working flow progress. In addition, the list of material that will be used had been discussed widely after the study of this machinery characteristic and performance. Then, the collection of data will be analysed and utilised. The procedure for the product work is shown step by step.

3.2   Overall Flow Chart

There will be 6 steps that are considered in the overall methodology that will be used to guide the overall flow in completing this project. Literature review, process planning, detailed design, software development, verification and analysis are the step involved. The aim of this project is program Programmable Logic Controller for an automated coolant supply system in CNC turning machine as well as to analyse the performance of automated coolant system in CNC turning machine in term of surface roughness and tool wear. It is shown in Figure 3.1
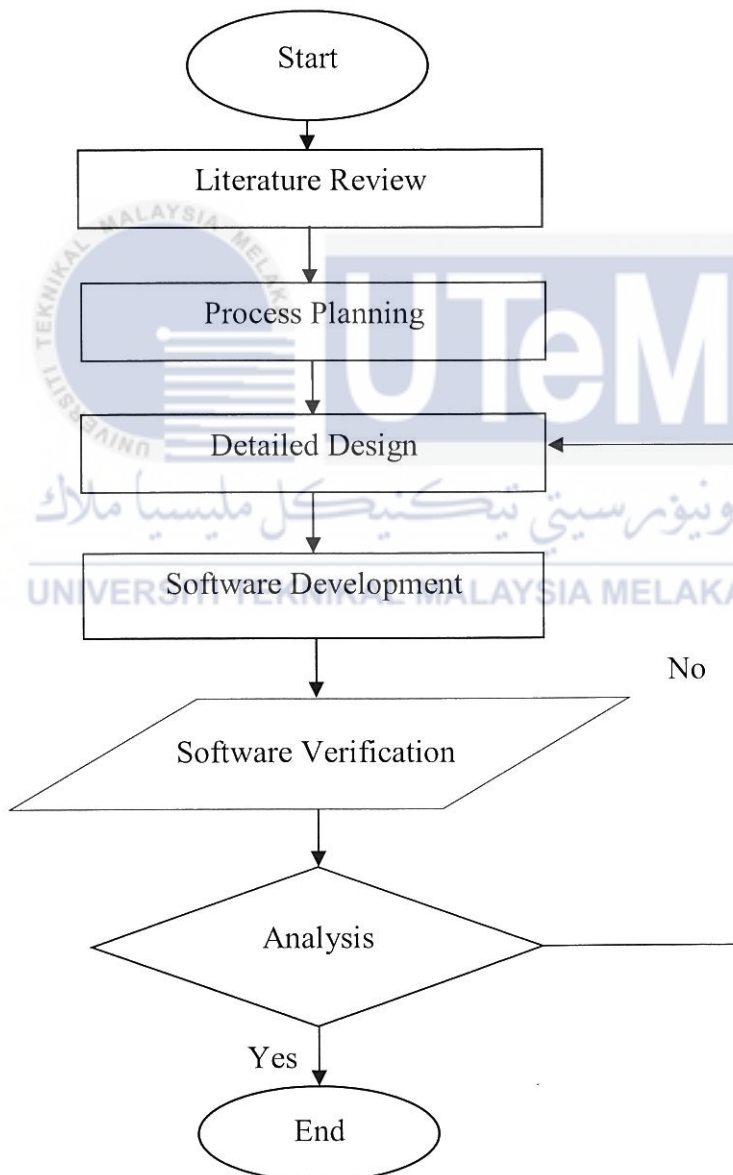

Figure 3.1: Overall methodology of the project

3.3 Literature Review

A literature review is grounded in the potential support that this research will bring to future work in the area, enabling better targeting by verifying trends and the evolution of the tools used in solving the problems being addressed (Ruschel *et al.*, 2017). A report was related to the selection of study including identification, screening and eligible. Firsts of all, it will be started by identifying the related topics about the main project. In this project, the main objectives are important to get the key information about the data that may be chosen. The process of identifying the sources such as journals, articles, books and internet helps to identify the problem and collect data through their combination. Thus, this will help to eliminate the potential weaknesses and then will bring to the potential strengths, in another word how to solve the problem. Next, it is consequent to use screening method in orders to save time. This method is used by reading through the abstract of each journal and papers to discover suitable and related information of the project. Once reading the whole contents, those eligible citations are taken and will be placed in the final report writing.

3.4 Process Planning

The development of the activities had been divided into two sessions. In other hands, the process planning for selected topic had been discussed and the flow of the data is collected. The cleaner application system in CNC Machine are discovered and the suitable software that is used in orders to achieve an objective is studied with multiple sources that had been explained in the literature review above.

The type of application had changed within the growth of technology. It causes considerate observation is needed to study the type and a few varieties of the required application system through many research. In addition, with the help of supervisor and technicians, MQL cleaner application system had been choose because of their sustainability and environmentally friendly. To meet the requirements, inspecting and testing are done using MQL cleaner system. Next, the process of choosing the PLC application is recorded. It is necessary to choose the application which can combine the types of input and output devices to meet the best and suit performance based on the main objective of the study. After

study the method, application and system development, the process of testing and debugging the system to prevent mistake will be created. The details about the software are explained briefly in the software development. Figure 3.2 shows the process planning in this chapter.
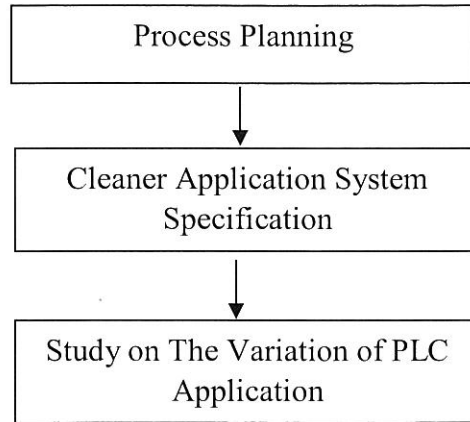
Figure 3.2: Process planning

3.4.1 Bill of Material (BOM)
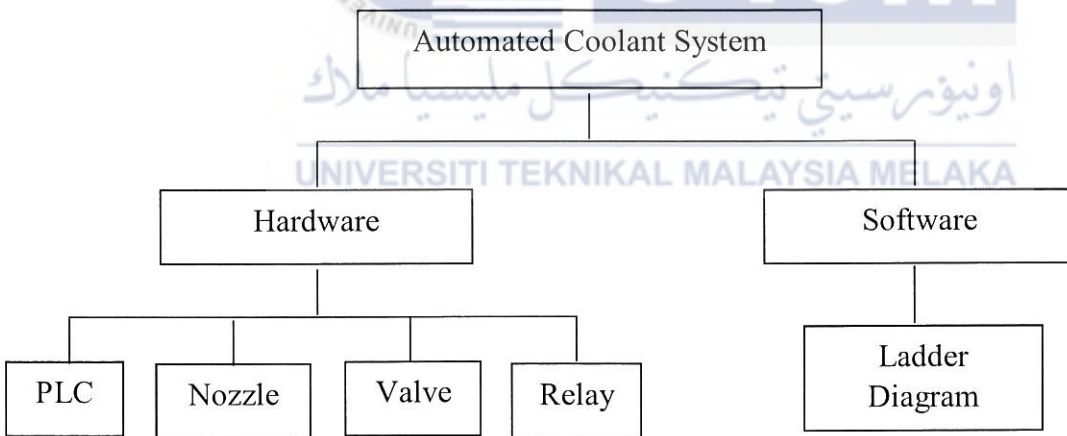
Figure 3.3: Automated coolant system

In building the automated coolant system, it is divided into two sections which are hardware and software. Figure 3.3s show the automated coolant system. Every part of hardware and software in automated coolant system has their own function and it helps in building the program. The hardware part will be discussed PLC, type of nozzle, valve and relay. This type of hardware that needs to be used will be explained briefly in the next page. Another one section is about software to program the exact time and amount of the coolants.

Details about ladder diagram and a prototype will be explained clearly after this. This section needed to analyse and to gain the result of the coolant automated system beside meet the main objective.

3.4.1.1 Programmable Logic Controller

A Programmable Logic Controller is a type of program that is used in industrial control systems using a special computer device to perform or run a program. It will be used to conduct differences input and logical manipulates the outcomes for desired control. In addition, there are three components that make a PLC work which are power supply and rack, the central processing unit (CPU) and input/output (I/O) section. The type of PLC that is used is shown in Figure 3.4.
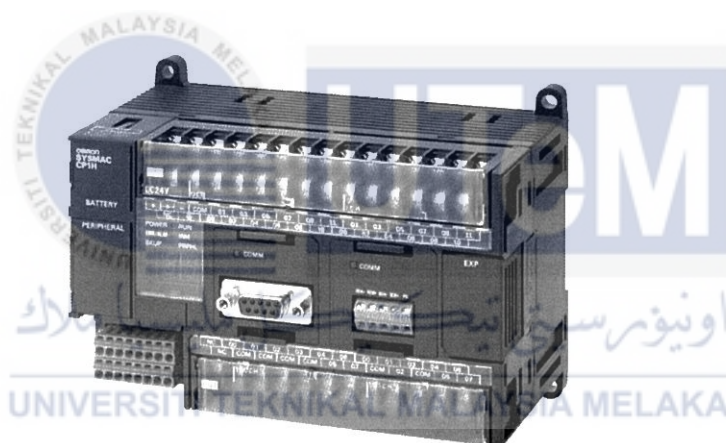
Figure 3.4: Programmable Logic Controller, Omron CPIE (Source: https://industrial.omron.us/en/products/cp1h)

While in this project, Omron CPIE PLC will be used. This module used 5V DC output to manipulate the computer circuitry and to control overall the system. It is function by converting the access AC power to DC power that required for the CPU and I/O modules. Moreover, the ladder diagram database that had been saved and stored will be used to control overall system as needed to analyse the data. It will start with the rack and supply power which is a component that holds everything together. This rack is used to hold more modules and it can be defined in different size depending on the needs of the control system. The power supply plugs into the rack regulated DC power to other modules that plug into the rack.

The input power supplies with 120 VAC or 24 VDC sources are used. PLC will obtain required voltage for internal circuit to commit controller process continuously. One cycle through the program is called a scan time and involves the reading in the inputs from the other modules. It will execute the logic based on these inputs and then updated the outputs accordingly. The I/O system provides the physical connection between the equipment and the PLC such as sensors and actuator. It is needed to sense the various parameter such as temperature, pressure and flow. Two types of I/O system are digital and analog. Next, LEDs, lights and relays are the examples of digital output card while a voltage and current represent an analog output card. Opening the doors on an I/O card reveals a terminal strip where the devices connect. Then, the range scan time is about 1/1000th of a second.

Meanwhile, the CPU that consists of user programs and operating system also has a memory to store the execute program and to hold I/O system to transfers the information. The data is stored between the communication of network and CPU. These communication modules are used for communicating with other PLC's and computers, which are placed at a remote place or far-off locate. There are a few principles to operate PLC by cyclic scanning and scan cycle.

In other to program the programming, ladder logic is used. This ladder logic used symbols to relay logic control instead of words. It will interconnect by lines to design the current flow through a relay for an example is the coils. When all the program is complete, it will look like a ladder but it is actually an electrical circuit. The left and right rails indicate the positive and ground of a power supply while the rungs represent the wiring between the different components which in the case of a PLC are all in the virtual world of the CPU.

3.4.1.2 Nozzle

Type of nozzle that will be used is important as a coolant in CNC Machining need to be chosen based on the application. In other hands, every type of nozzle has different functions and Plastic Flexible Coolant Pipe Valve is chosen to test the machinability performance. This coolant pipe is used based on the performances;

- Flexible body make it easy to change the direction and angle

- Made of plastic material

- Non-toxic feature

- Resistance to corrosion and tension

- Long service life

Figure 3.5: CNC lathe machine plastic nozzle (source: https://ru.aliexpress.com/item/5Pcs-1-4-Nozzle-Plastic-Flexible-Coolant-Pipe-Valve-Milling-Lathe-Milling-CNC-Machine-Switch/32527013809.html)

Moreover, the length of projections can be adjusted to test the effect of the length to the surface roughness. The plastic nozzle that is used as shown in Figure 3.5. Short projections usually more compact and are less likely to be knocked out of position by swarf or vibration. Meanwhile, extension that is longer easier to aim, produce a more laminar flow and shoot farther.

3.4.1.3 Valve

The inlet valve used to manage the flow of the coolant to the workpiece. In other words, it acts as gatekeeper when the electrical sent signal to the valve to allow the flow into the tub. Meanwhile, the tub will be close when there is no electrical signal. This start when the machine is on. The machine will send a signal to the solenoid to control a particular gate.

After that, this solenoid will tell the gate to be opened to allow the flow of water. The valve that is used is shown in Figure 3.6.
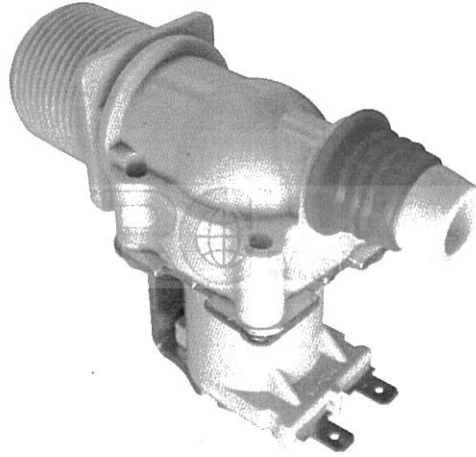
Figure 3.6: Proportional flow control valve (Source: http://www.xetremotecontrol.com/index.php?ws=showproducts&products_id=606555&cat=WAS HING%20MACHINE%20SPARE%20PARTS&subcat=INLET%20VALVE)

3.5   Design

From the planning process, it can be said that the design is one of the most important things in the project. The sketching, details drawing, assemble and the development of the design are the process involved in this step. The overall design of Automated Coolant System which is hardware design is shown in Figure 3.7. The nozzle is design using SOLIDWORK software. A nozzle with diameter of 60mm had been used before and it is broken due to high pressure of the coolant. Therefore, a new design is proposed to overcome this problem.
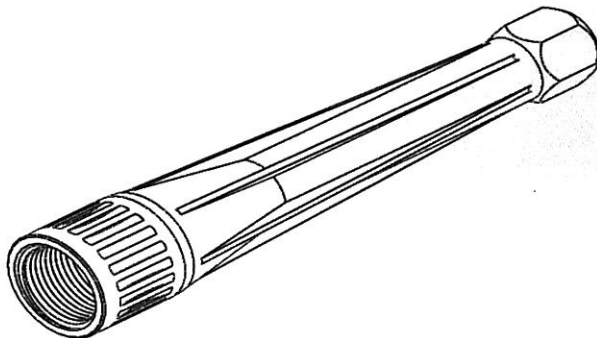
Figure 3.7: Design of nozzle

3.6 Development

This section involved development in software hardware. There are two parts in the hardware development which are electrical part and mechanical part. The process of assembling the part will be shown below. Then, the software development involves ladder logic and ladder diagram. It shows that there is a connection between input and the output and it is clearly seen by studying the ladder logic and ladder diagram. Figure 3.8 shows the flowchart of the development process.
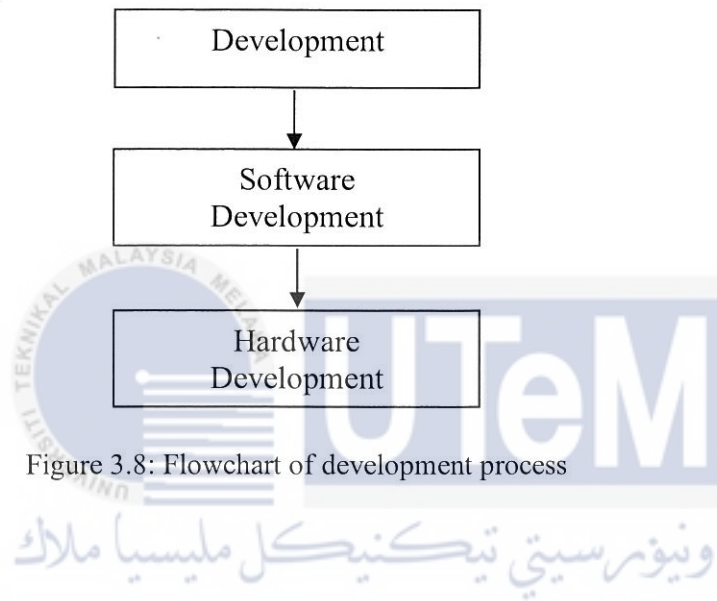
Figure 3.8: Flowchart of development process

3.6.1 Software Development

In the software development, PLC (Programmable Logic Control) had been selected as the main software to control automated coolant system as it is one of the required parts to construct this project. This software was chosen because the development of the program can be constructed manually using PLC Basics and it also the beginner software to serve some users. Ladder diagrams are the type of schematics and usually used to file industrial control logic systems. The process of testing and debugging the system to prevent mistake will be created as shown in Figure 3.9.

In order to achieve the ideas of the project, a deep investigation about software used has been taken and were explained clearly to get full result of the experiment. PLC software had been chosen as software development to design the coolant automated system. The

details of development software and the flow chart for this software had been explained one by one.
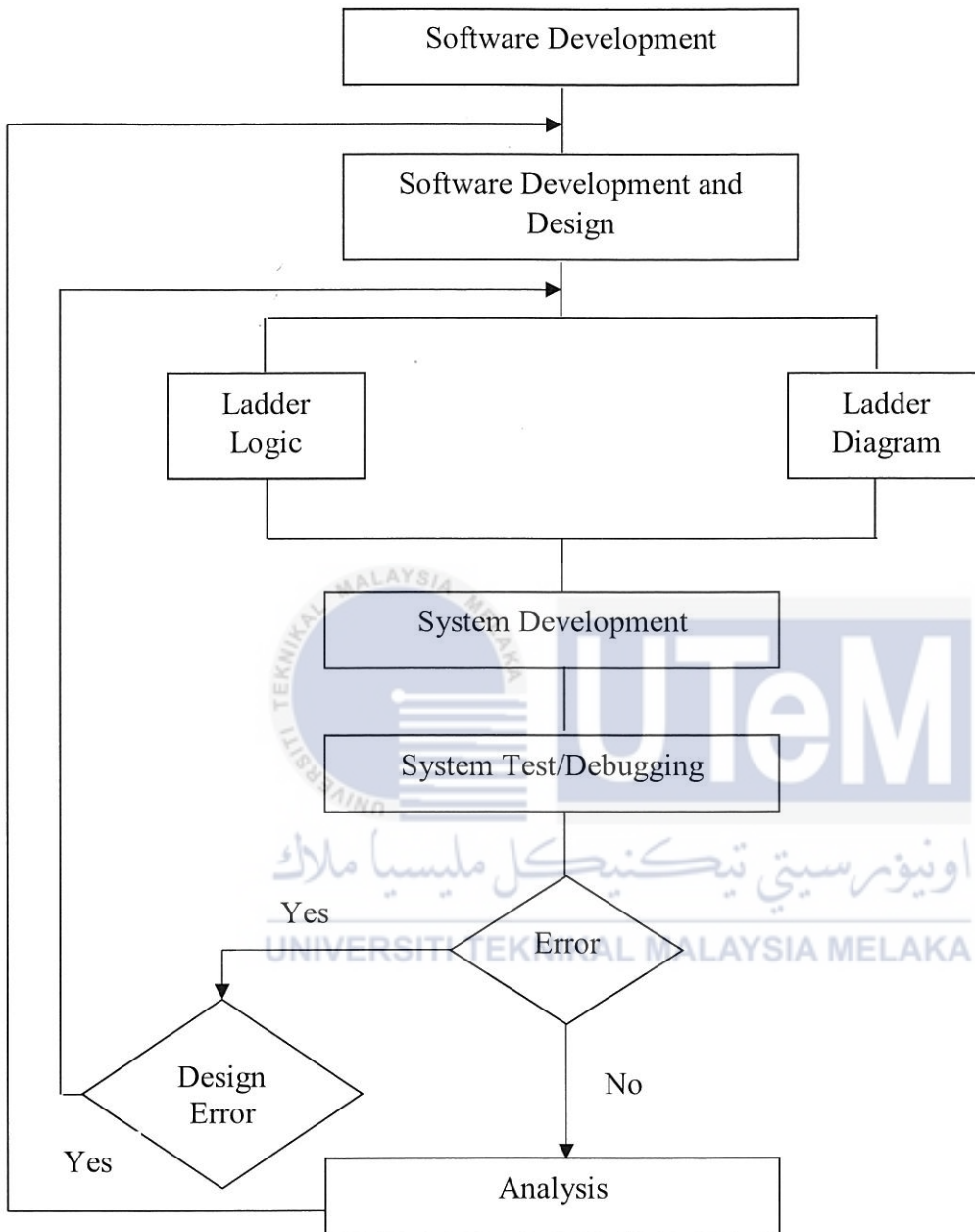
Figure 3.9: Flowchart for software development process

It starts by choosing the suitable software development which is PLC software. After that, the right design needs to be taken to set the exact timing as required in the experiment to control time-based coolant supply. In developing this PLC software, it had been divided into two which is on ladder logic and ladder diagram. This ladder logic or programming language represents a program that basically depends on the circuit diagrams of relay logic

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hardware by a graphical diagram. Meanwhile, the ladder diagram is used to record the programming language.

Besides, the process of testing and debugging the system was created to check the programming mistake. It is a necessary process since the function of the process is to run the program by looking at the input and output doing their job. Some error can be detected if the program cannot be run. This is maybe due to the mistake in the building the programming language and the details design need to be redesign. After that, the test will be debugging again until no error found in the system. Next, it will proceed to the analysis phase.

3.6.2 Hardware Development
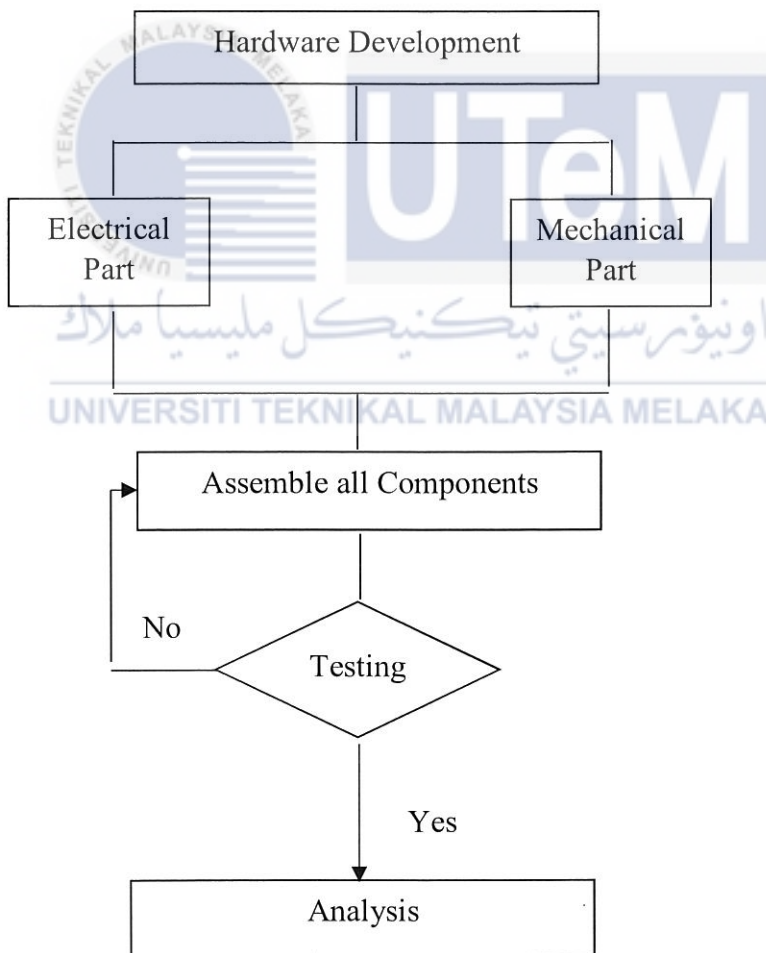
Figure 3.10: Flowchart for hardware development process

Figure 3.10 shows the flowchart for hardware structure that consists of the development in mechanical part and electrical part. The part involves in hardware development is PLC Omron, nozzle, valve and relay. This is because each component has their own function and it helps in building the program. After the components are assembled, it is tested to analyse the function of the system. Then, the whole system is tested again with the combination of hardware and software development.

3.7   Analysis

In this analysis phase is to test and do a measurement based on the coolant system involving difference experiments. A few tests will be set up to get the required data that are needed for the project. Turning machines will be used in this analysis phase to gain the performance of the machines in term of tool wear and surface roughness using PLC software prototyping. The results obtained from the experiments are then analysed.

3.7.1   Experimental Setup
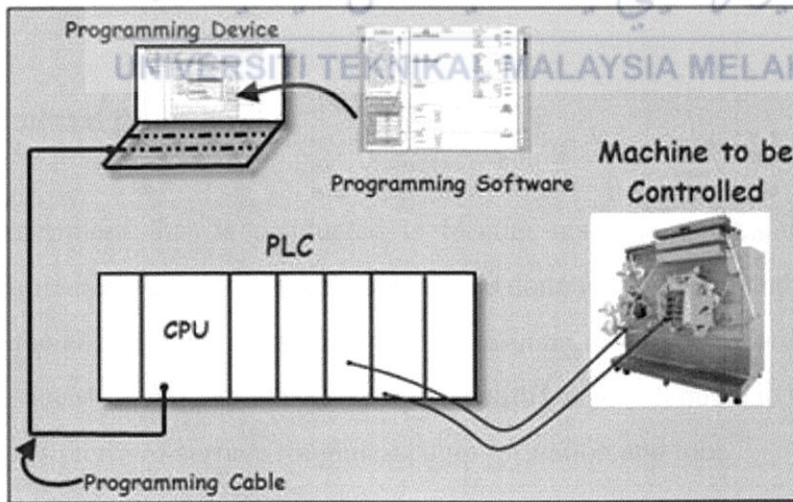
Figure 3.11: The diagram for the system

There are 4 types of setup involves in this project. The first is software setup required to set the timer to control the flow of the coolant. The input which are start and stop button is used. In the system, the start button is used as normally open and the stop button as a

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normally closed button. Then, there are 4 output which are light, valve and two timers. The program needs to be debugged by using CX-Simulator before executed to the Omron PLC.

Then, electrical part setup had been done by assembling the switch, Omron PLC, connector, relay, power supply, nozzle, and plug build a perfect circuit to control coolant system in CNC turning machine. It is tested after the assemble parts had been done to check the correction in wiring and the function of the system.

Next is mechanical setup, the used of the inlet valve is to control the fluid that is supplied to reduce the cutting temperature at the workpiece. To prevent the leakage, hot glue and white tape are used to attach pneumatic fitting, coupling and the valve. After that, the length of projection and the position of nozzle need to adjust to the suitable position and the length as needed in the experiment.

Lastly, the overall system to run the experiments are setup with turning machine. This experiment conducted in Haas SL-20 CNC Turning Machine with the aluminium type of workpiece. 30 mm diameter of workpiece with 100mm and 200mm distance of cutting process are used to get the best interval time in term of surface roughness and tool wear. The combination of the parameter are used to get the exact data needed in this experiment.
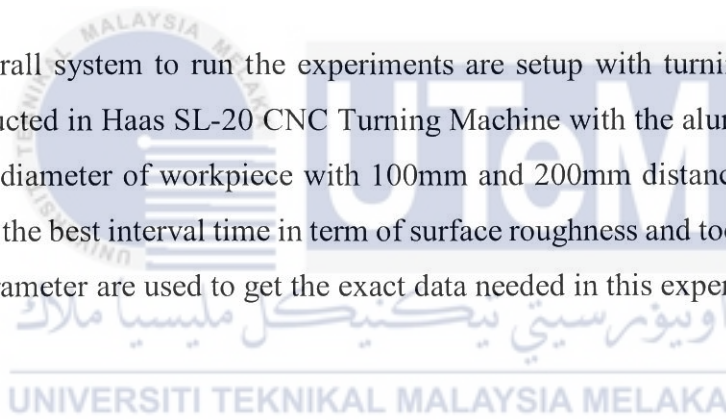
3.7.2   Experimental Procedure

The experiment that is conducted is turning machine to examine the cooling technique performance. First, the experiment will be done without load and this experiment is made to run the coolant system using new PLC program. It will be recorded to prove that the program is success as require. Next, experiment with a load will be set to test and measure the performance in term of surface roughness, chip formation and tool.

Experiment conducted:

1. Best interval of:

   ✓ Surface roughness

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✓ Tool wear

2. Optimum condition of feed rate, depth of cut and speed.

Besides that, different tools will be used for differences timers in order to test if the tools affect the surface roughness. The data obtained from the overall experiment will be recorded.

3.7.2.1 Test performance of unloaded coolants

In this experiment, the coolant supply is used to see the performance of the CNC machine. It is documented using PLC programming language in the turning machine. A few steps are shown to complete the experiment.

Step 1: Setting up the coolant supply system.

Step 2: Setting the timing in PLC programmable for the coolant supply.

Step 3: On the CNC machine and start the supply coolants.

Step 4: Observe and record the condition of the coolants.

Step 5: Tabulate the data.

3.7.2.2 Performance Analysis

The aim of this project can be stated to compare the CNC machinability performance using new PLC program using turning machine. 8 differences timer will be set to test the performance of machine by compared it in term of surface roughness and tools wear.

Step 1: Attaching the automated coolant supply system to CNC machine.

Step 2: Adjusting the position of the nozzle to the specific position which can supply the coolants.

Step 3: Placing the Aluminium workpiece on the work table and clamp firmly to prevent it from moving.

Step 4: Setting the timing for the coolant to be supplied.

Step 5: Start the process.

Step 6: Observe and record the data of the surface roughness, chip formation and tooling.

Step 7: Repeat the experiment using differences timers.

Step 8: Collect the data of the machine and plot the graph.
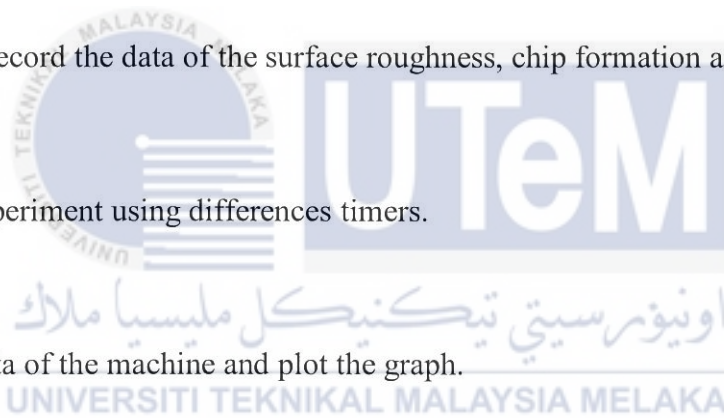
3.7.2.3 Tester

The function of the roughness tester is to test the workpiece performance. The measurement can be taken easily by putting it on the aluminium workpiece after running the machine. From the value that will show by the tester, the details graph can be developed in order to get the best interval of the surface roughness. Figure 3.11 shows the tester for surface roughness.
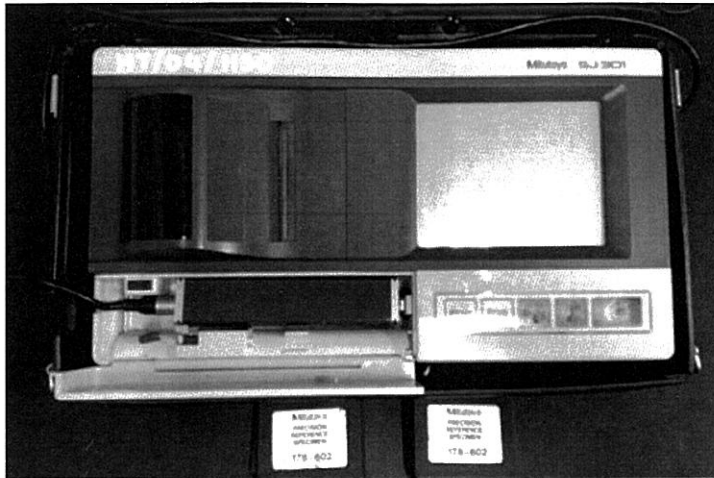
Figure 3.12: Tester for surface roughness

3.8   Summary

Therefore, a brief discussion about the flow of this project had been seen important as a guide to solve the problems and to achieve an objective of this project. It is started by listing the problems statements that involve in this CNC cooling system. Then, followed by literature review as the past research that was done by others. The idea of using PLC to replace the manual automated coolant is inspired as the control system plays a main role in developing and advancing the modern technology and industry due to high numbers of demand and also to maintain the quality of the product that will produce.

CHAPTER 4

RESULT AND DISCUSSION

This chapter explaining details of software and hardware development. Then, discussion of the data obtained from three difference experiments is explained clearly through graphs and several methods. The final results are analysed and discussed briefly for each detail involved in the experiments to achieve the objectives.

4.1 Software Development

As discussed in Chapter 3, the PLC of Omron CPIE is used to control timer for coolant system in CNC turning machine. The program is programmed using CX-Programmer. This CX programmer allows the differences in the integration between features and I/O units. This situation reduced the time used since the program that created is easy and suitable for the beginner. Moreover, this software gives a simple drag and drop configuration.

Design, online debugging on actual machine and startup is the work for the PLC system configuration. CPIE model is chosen as a new CX-Programmer. Then, 2 inputs which are start and stop button are used. In the system, the start button is used as normally open while the stop button as a normally closed button. Next, some of the outputs that had been declared in the system are light, valve and two timers. Each of the input and output gave a specific address for making the programming. Besides the program is debugged by using CX-Simulator, which is a ladder simulation tool without PLC.

Furthermore, the online connection button is pushed to allow the relationship between the PLC and CNC turning machine. Then, the program and the configuration data are transfered at the same time to the CPU Bus Unit and Special I/O units. After that, the program is debugged.

4.1.1 Ladder Diagram

A flow chart is designed to display the development of the ladder diagram. It is shown in Figure 4.1. The inputs involved in the system are open and stop button while some of the outputs are light, valve and two timers are applied.
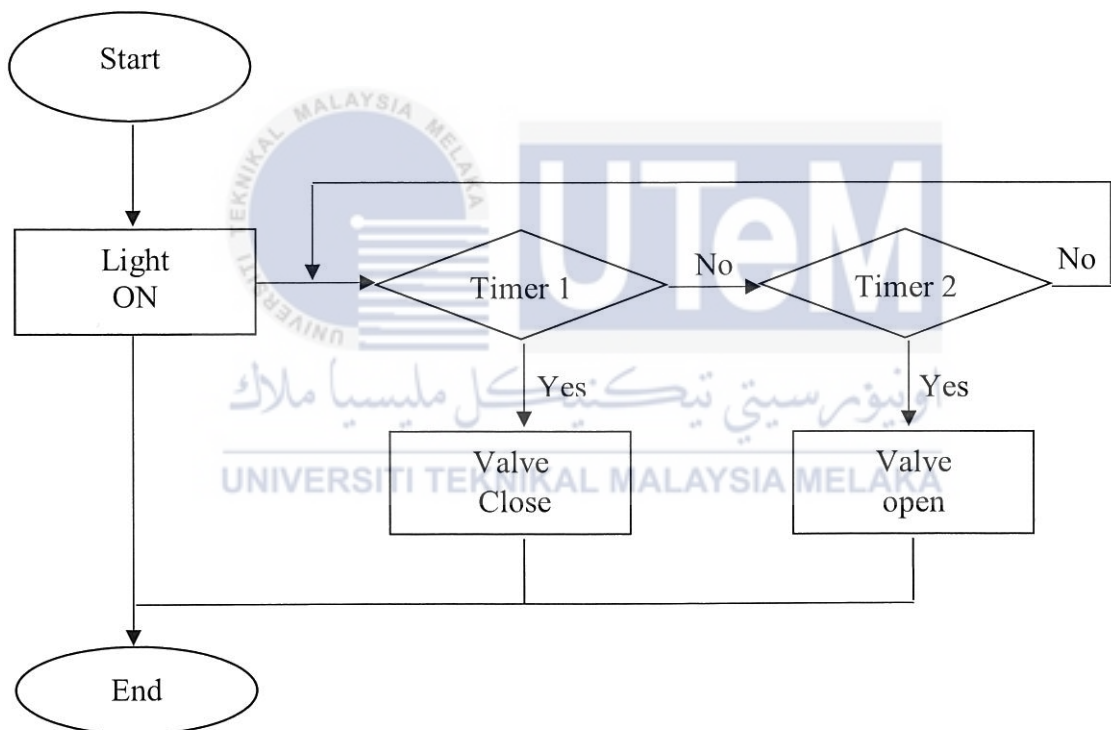
Figure 4.1: Flowchart of development of a ladder diagram

The signal is transmitted when the start button is pushed. The light will automatedly become lightened and the circuit is activated by the flow of electricity. Then, the instruction transmitted to timer 1 will close the valve. When timer 1 deactivated, timer 2 is activated and the valve is opened. The cycle will be repeated continuously if timer 2 is deactivated. The cycle is stop repeating if stop button is pressed.
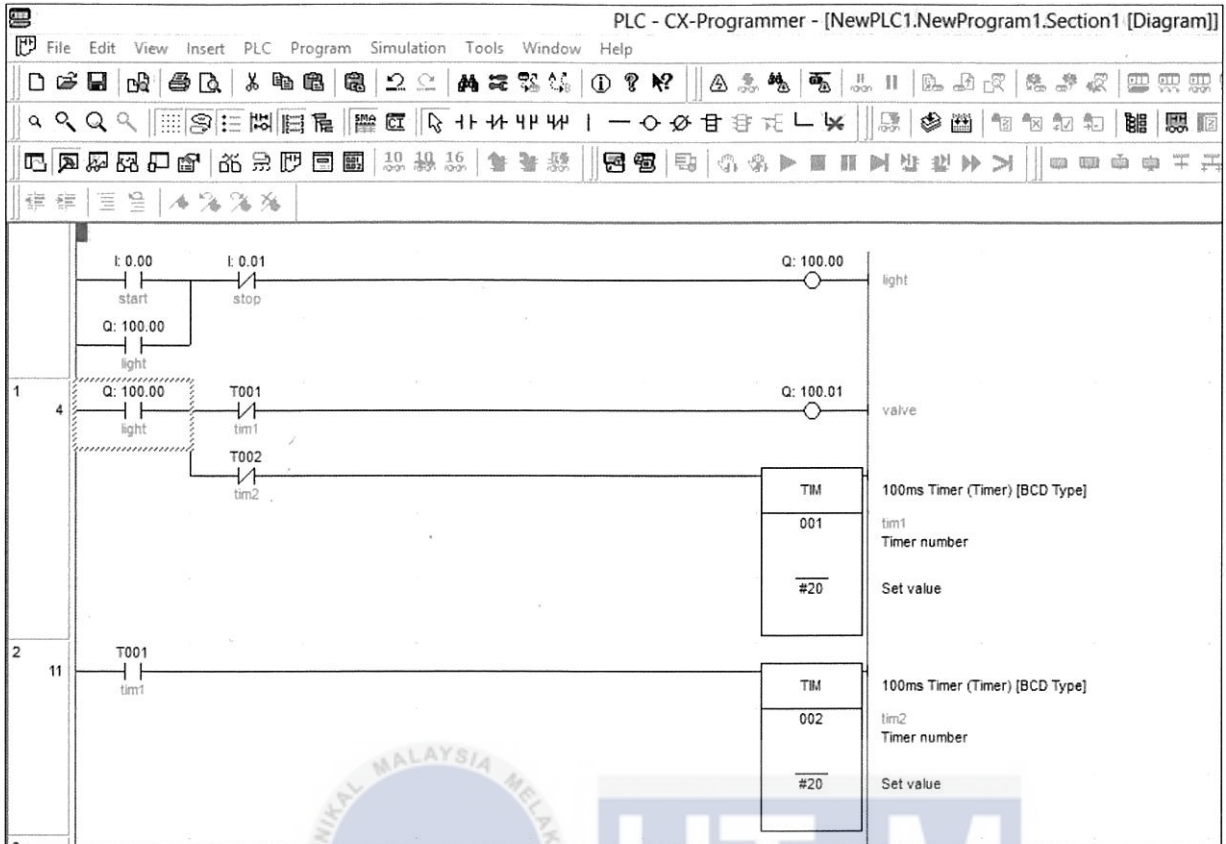
Figure 4.2: Ladder diagram schematic in CX-Programmer software

In rung 0, the specific address for start button is I:0.00 while the stop button is I:0.01. The start and stop button are used in a normally open. Then, the light is located at Q:100.00 which is used as a relay. It will then continuous latching although the start button is released.

Next, continue with rung 1 and rung 2, where timer 1 is normally close button and located at the same rung with the valve while timer 2 is also normally close button but it is located in rung 2 with timer 1. In rung 2, timer 1 is normally open and it functions as the input which activates timer 2.

When timer 1 is activated, the normally closed button in rung 1 row 1 will open and it will stop the transmission to the valve. At the same time, timer 1 in rung 2 will close and it will activate timer 2. After timer 2 is activated, timer 2 in rung 1 row 2 become open and it will stop the transmission to timer then the valve is back in operation.

Hence, the valve will stop operating when timer 1 is activated while it will start operating back after timer 2 is activated. This cycle is continuously run until the stop button is pressed.

4.1.2 Preliminary Test

The main purposes of this project by using interval time is to control coolant system in CNC turning machine. PLC program is used is to conduct the experiments. Hence, 8 difference timers are used in order to give command to the valve whether open or close and this system is connected to the CNC turning machine. Therefore, a preliminary test had been carried out to observe the functionality of the PLC using ladder diagram.

4.1.2.1 Communication with PLC

The ladder diagram module is uploaded from the CX-Programmer to the PLC. The uploading of the program into PLC is created to see the functionality of the PLC. But first, the test is done by running the process of the ladder diagram in the laptop.

Figure 4.3 shows the green colour in rung 0 and rung 1. This happens when the start button is pressed and the light button will continue latching to open the valve (coolant supplied). The valve is open until timer 1 is activated.

When timer 1 is activated, the normally closed timer in rung 1 row 1 is opened and it will close the valve (coolant stop supplied). At the same time, the normally open timer 1 in rung 2 become energized and timer 2 starts counting. Then, the process will be repeated and the stop button needs to be pressed to stop the cycle.
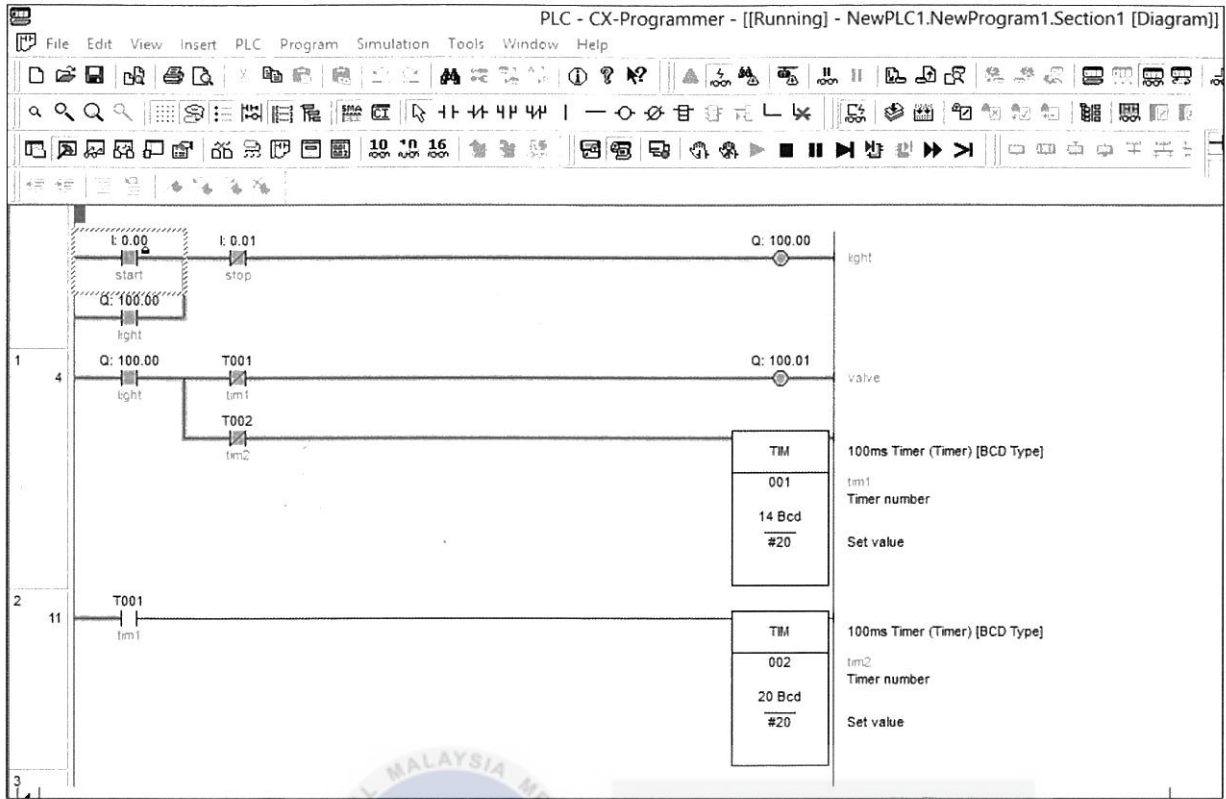
Figure 4.3: Result when the start button is pressed
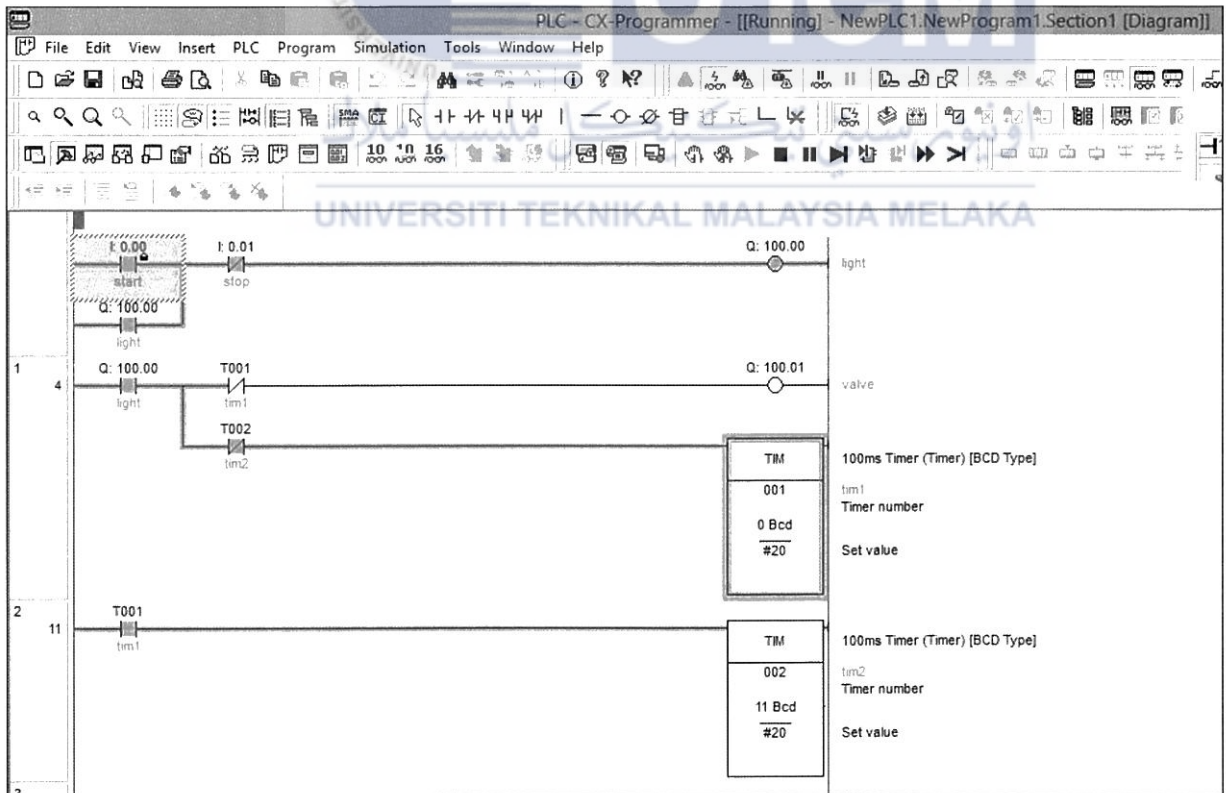
Figure 4.4: Result when timer 1 is activated

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4.2 Hardware Development

In hardware development, it consists of the electrical part and mechanical parts. Electrical part divided into several basic discrete devices and most of them are components that are used in the industry. All of the components are connected to each other to form a circuit and produce electricity. It is then linked together to the CNC machine to test the performance of PLC under high pressure and to ensure well operation.

4.2.1 Electrical Part

There are a 220V power supply, relay, ON/OFF switch button and Omron PLC linked together in the electrical part. The power supply supplied 220V alternative current that converts from AC to DC. The alternative current then linked to the Omron PLC that was already programmed and it is connected to the valve to control open and close of the valve.
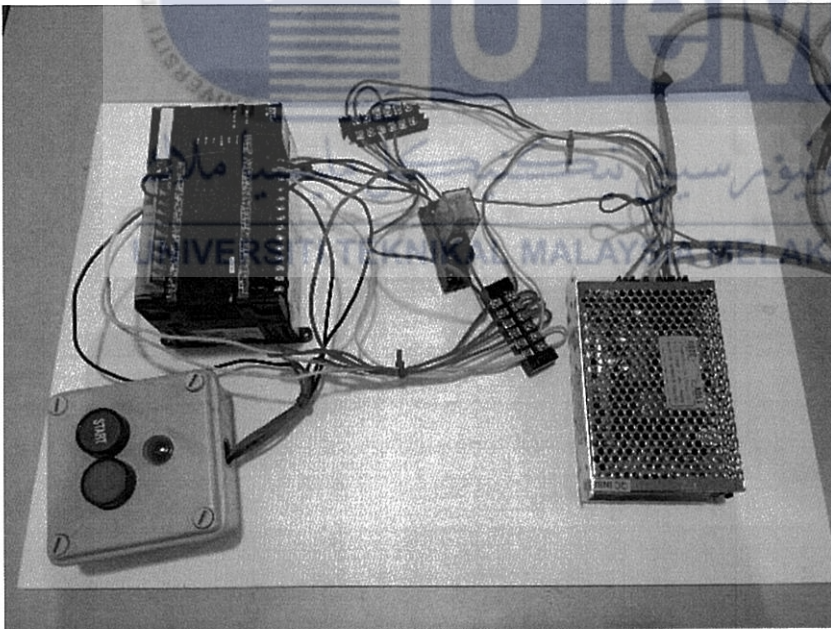
Figure 4.5: Electrical wiring

Figure 4.5 shows the full wiring for the electrical part. The wiring is based on the PLC programming that is programmed in CX-Programmer software. As explained in the software development before, it had two inputs and four outputs. The input signal is activated when the button is pressed, then it will give a signal to the Omron PLC to run the circuit.

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Moreover, the power supply is connected with a plug as an input and a nozzle as an output while other connectors in power supply are linked with relay and Omron. Therefore, the combination of switch, Omron PLC, connector, relay, power supply, nozzle, and plug build a perfect circuit to control coolant system in CNC turning machine.

4.2.2   Mechanical Part

In mechanical part, the design of nozzle as shown in Chapter 3 (Figure 3.7) is printed using a 3D printer. The aim is to connect the nozzle and the valve to the CNC machine to flow out the coolant. The nozzle has 172.5mm length with 34mm diameter. Figure 4.6 (a) and (b) shows 8mm tube fitting to connect a tube to the nozzle. Moreover, two type of tube fitting is used which are tube fitting with one tube and another one is tube fitting with two tubes.

(a)   (b)
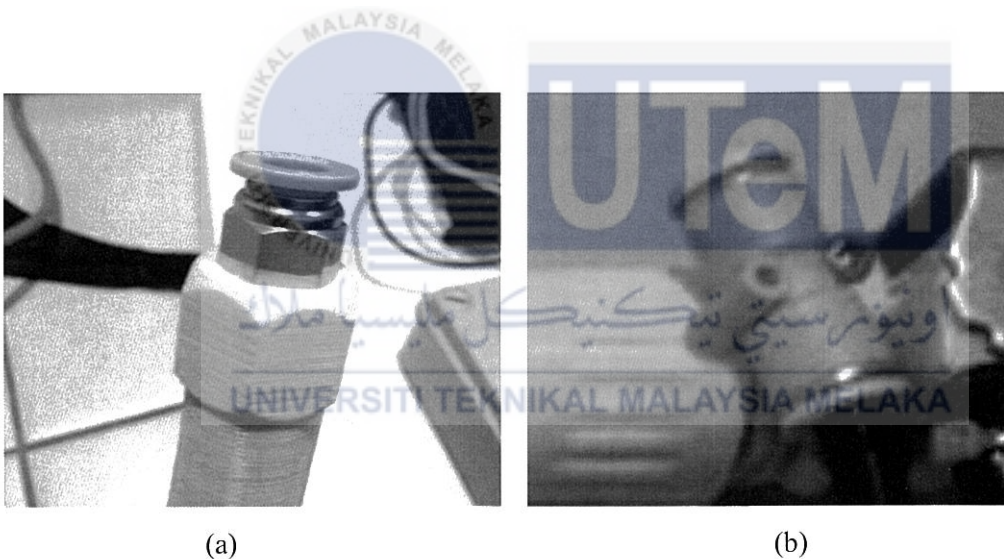
Figure 4.6: (a) 8mm tube fitting for one hole and (b) 8mm tube fitting with two holes
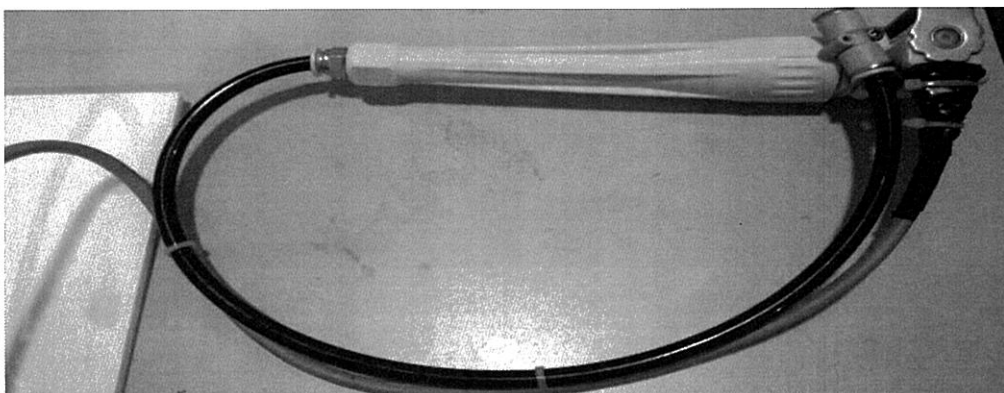
Figure 4.7: Connection of the mechanical part

The connection of mechanical part is displayed as Figure 4.7. Two 8mm tube fittings are connected with the nozzle to flow out the coolant in order to get the best surface roughness. The open and close of the valve is controlled by the electrical part that had been discussed before.

4.2.2.1 CNC Machine Connection

Figure 4.8 presents how the nozzle is placed in the CNC turning machine. The installation is quite difficult since the tool turret that holds the valve is not static and can be changed by programming the computer at the machine. A nylon cable tie is used to attach the nozzle and tool turret to ensure the nozzle is well tied especially while the machine is run. This is because some movement of the nozzle will affect the performance of the CNC turning machine.

Figure 4.8: Nozzle and valve attached to the CNC turning machine

4.2.3 Unloaded Test

The first evaluation to prove the success of the whole systems is by testing the system without load. By turning the plug on, the valve is set to normally open and the push button at the electrical part is pressed. Then, the coolant from the machine flow out through the valve and nozzle. The open and close of the nozzle are set to 5s timer in Omron PLC to perform this experiment.

A screenshot had been taken as an evidence to show that the experiment had been done. Figure 4.9 displays that the coolant started to disperse from the nozzle at 0.00 period and Figure 4.10 shows the coolant stop dispersed at period 0.05. Lastly, at 0.10 the coolant started to disperse again as presented in Figure 4.11. This show that 5-seconds unloaded test is achieved which means that the whole system can be used to prove the performance of CNC turning machine for the surface roughness and tool wear.

Figure 4.9: At the 0.00 period, the coolants start dispersed from the nozzle

Figure 4.10: At the 0.05 period, the coolants stop dispersed from the nozzle

Figure 4.11: At the 0.10 period, the coolants start dispersed from the nozzle again

4.3 Experimental Result and Analysis

As stated earlier, there are two data that need to be obtained which are surface roughness and tool wear. Differences method and tools are used to collect the data. Therefore, the best results are explained clearly after the experiments done.

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The surface roughness of the experiment is measured using Mitutoyo Surface Roughness Tester SJ-310 manual. The value of 2.5mm cut-off is used to increase the accuracy of the obtained reading. Then, 9 times of the reading are taken for each experiment. After that, the average is calculated to analyse the result. Table 4.1 shows the feature of the surface roughness.

Table 4.1: Feature of surface roughness

Standard	**JIS 1994**	Cut-off Length, λc	**2.5mm**
Profile	**R**	Λs	**8μm**
Filter	**GAUSS**	M-Speed	**0.5mm/s**
Eva-Length	**7.5mm**	Range	**AUTO**

4.3.1 Experiment 1 – Best Combination of Parameters

The purpose of this experiment is to find the best combination of parameters that give the best surface roughness when it is tested with Mitutoyo Surface Roughness Tester. Johnson *et al.* (2014), stated that the selected input parameter is varied at 3 levels and the selection of parameter is done based on earlier work application. The value applied is shown in Figure 4.13.

Input parameter	Level 1	Level 2	Level 3
Cutting speed [m/min]	128.64	148.44	168.23
Feed [mm/rev]	0.04	0.06	0.08
Depth of cut [mm]	0.5	0.75	1.0
Pressure at the fluid injector [Bar]	50	75	100
Frequency of pulsing [Pulses/min]	500	700	900
Rate of application of cutting fluid [ml/min]	3	6	9
Composition of cutting fluid [%]	10	20	30

Figure 4.12: Parameter and Levels for experimentation (Source: Johnson *et al.*, 2014)

The parameter given is in m/min but the machine used is only varied in rpm. Therefore, a formula is used to convert the cutting speed from m/min to rpm. This

experiment is tested with flooded coolant with 100mm of cutting length for each run. A gap of 5mm is created for each run to distinguish between them.

$$Cutting\ speed = \frac{\pi \times D \times s}{1000} \qquad\qquad Equation\ 3.1$$

$$S = \frac{1000 \times cutting\ speed(\frac{m}{min})}{\pi \times 30mm} \qquad\qquad Equation\ 3.2$$

4.3.1.1 Combination Using Minitab

To start the experiment, the combination of speed, feed rate and depth of cut is exerted with difference values. The value of feed rate is used lower than the journal that is studied due to the condition of the CNC turning machine that is also need to be considered.

- Speed – 1365rpm, 1575rpm, 1785rpm

- Feed rate – 0.02mm/rev, 0.04mm/rev, 0.06mm/rev

- Die of cut – 0.5mm, 0.75mm, 1.0mm

Using Minitab and Taguchi Method, 9 best combinations can be utilized to analyse the best surface roughness. In Figure 4.13 there are steps involved in creating Taguchi design. First is to select DOE in a stat. Then, Taguchi is chosen to create Taguchi design.
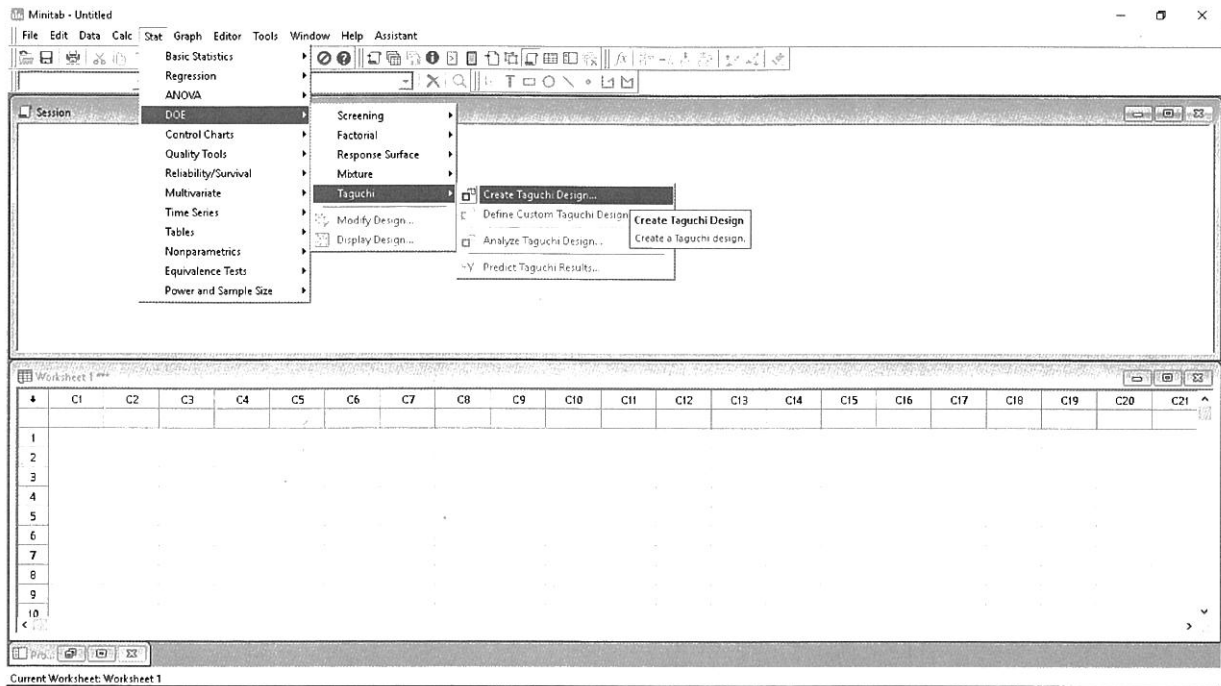
Figure 4.13: Step to used Taguchi method
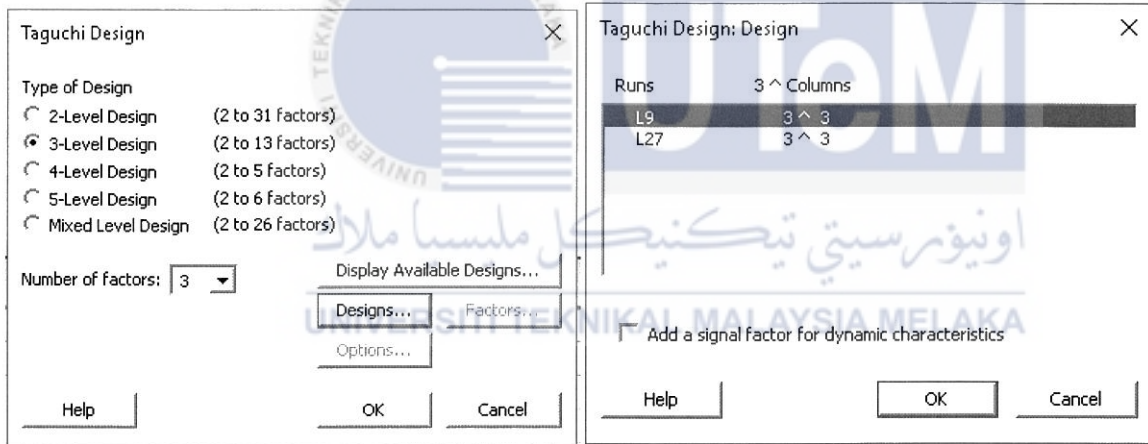
(a)   (b)

Figure 4.14: (a) Taguchi level and number of factor and (b) Number of runs

In figure 4.14 (a) and (b), 3 level of design with 3 number of a factor is selected as there is three type of parameter that needs to be the analysed. The analysis involves speed, feed rate and depth of cut. In this experiment, it is decided to limit the experiment within 9 run due to the decreasing number of the workpiece.
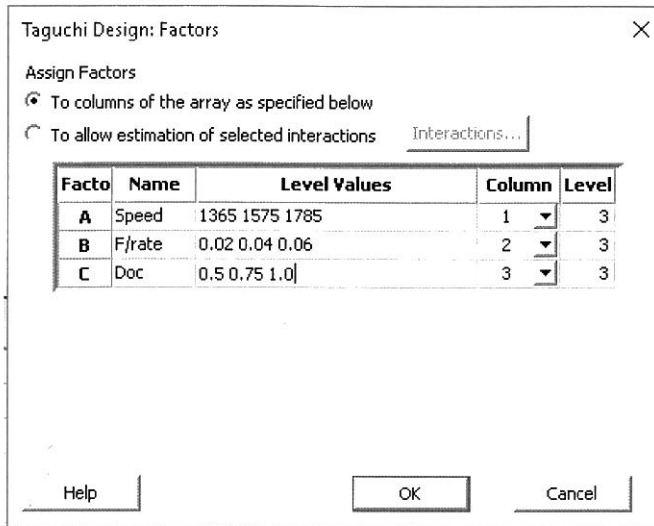
Figure 4.15: Parameter added
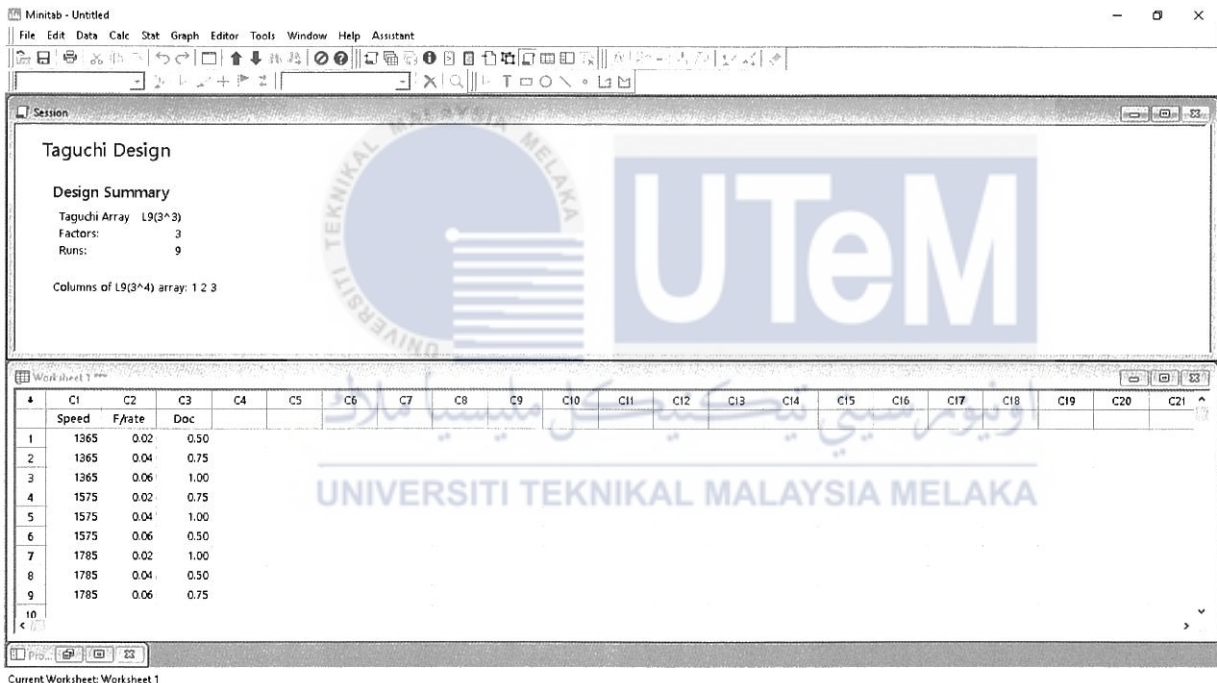
Figure 4.16: Combination of speed, feed rate and depth of cut

Figure 4.15 shows the difference parameters are added to the column and Figure 4.16 shows the combination of speed, feed rate and depth of cut with 3 number of the factor and 3 level of design. It created 9 best combinations and this combination is used to get the best surface roughness. Therefore, one combination that has the best surface roughness can be used to run Experiment 2 and Experiment 3.

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4.3.1.2 Combination Result

Table 4.2: Best Combination of Parameter Result

Cutting speed (rpm)	Feed rate (mm/rev)	Doc (mm)	Average, Ra (µm)
1365	0.02	0.5	0.596667
1365	0.04	0.75	0.601111
1365	0.06	1	0.664444
1575	0.02	0.75	0.366667
1575	0.04	1	0.248889
1575	0.06	0.5	0.732222
1785	0.02	1	3.342222
1785	0.04	0.5	3.363333
1785	0.06	0.75	2.785556

Table 4.2 shows the result of the best combination of the parameter with an average value. It is shown that combination of 1575 rpm cutting speed, 0.04mm/rev feed rate and 1mm depth of cut with the average value of 0.248889 have the best surface roughness. Then, the cutting workpiece for the best combination of parameter is shown in the Figure 4.17.
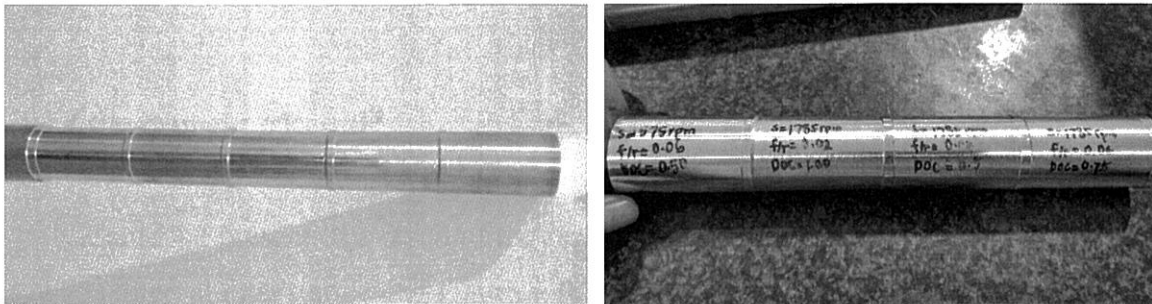
(a)   (b)

Figure 4.17: (a) the cutting workpiece for the best combination of parameter for 2 to 10s and (b) the cutting workpiece for the best combination of parameter for 15 to 25s

4.3.1.3 Discussion

From the observation discussed, surface roughness with cutting speed 1785rpm has higher average value than 1575rpm and 1365rpm. It can be understood that best surface roughness is express with the lowest value of the average reading. From the data, the combination of 1575 rpm cutting speed, 0.04mm/rev feed rate and 1mm depth of cut is defined as the best surface roughness with the average value of 0.248889µm. Therefore, the smoothness of the surface roughness is not only because of cutting speed but it is depended on the combination of three parameters which are cutting speed, feed rate and depth of cut.

4.3.2 Experiment 2 – Interval time 2s to 25s (Ascending)

Next, experiment is proceeded with Experiment 2 by using 1575 rpm cutting speed, 0.04mm/rev feed rate and 1mm depth of cut. The aim of this experiment is to use PLC program to control time-based coolant supply with 8 difference interval times. For each 2s, 3s, 4s, 5s and 10s interval time the length of the workpiece are 100mm while for 15s, 20s and 25s interval time, 200mm of the workpiece is used. The arrangement of the interval time is arranged between 2s to 25s. In this experiment, the lowest number of surface roughness will be selected as the best surface roughness. The result can be seen from the average value of the data and the graph.

4.3.2.1 Experiment 2 Result

Table 4.3 presents the result of the surface roughness of workpiece which cut under 2s to 25s interval time started and Figure 4.18 shows the graph for the surface roughness vs interval time. From the data obtained, the best surface roughness that has the lowest value is on the interval time of 25s. The reading of the surface roughness is taken 9 times and the average value for that interval time is 0.291111.

Table 4.3: Interval time 2s to 25s result

Time	Average (µm)
2s	1.200000
3s	0.464444
4s	0.436667
5s	0.345556
10s	0.312222
15s	0.832222
20s	0.320000
25s	0.291111
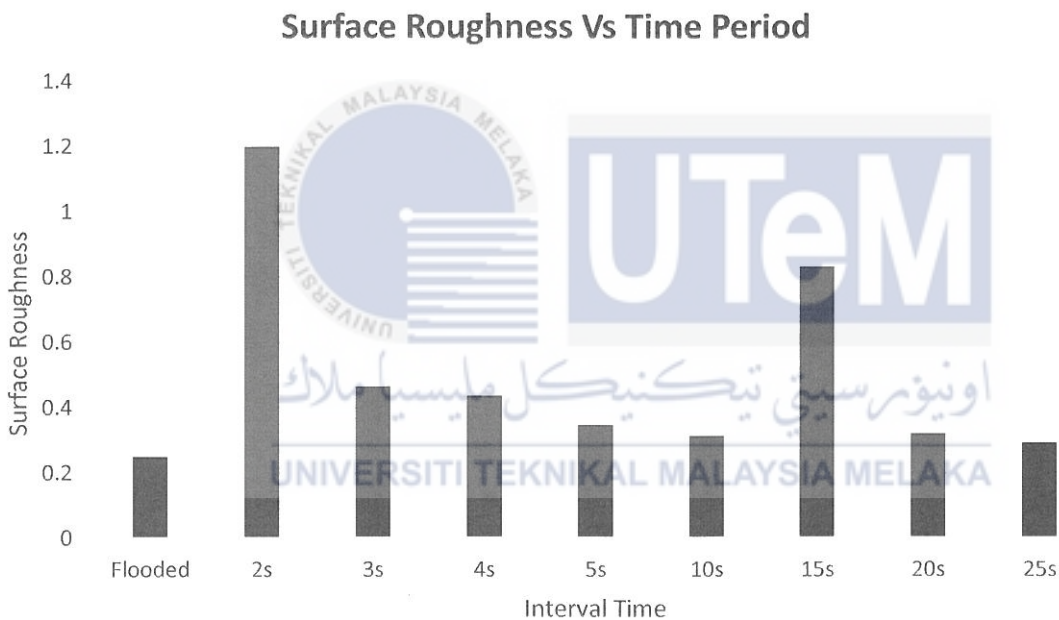
Figure 4.18: Graph surface roughness vs interval time for 2s to 25s

4.3.2.2 Discussion

The data from Experiment 2 shows that interval time for 2s had the highest average reading while interval time for 25s had the lowest average reading for 1.200000µm and 0.291111µm. Based on the graph of Figure 4.18, from 2s to 3s the average value for surface roughness dropped significantly from 1.200000µm to 0.464444µm. Supposing that this situation did not happen except for a technical problem. This is probably because some

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vibration had occurred during the experiment for interval time 2s due to the unstable clamped. It happens since that 2s was the first run conducted in Experiment 2. Figure 4.19 displays how the workpiece is placed and clamped.
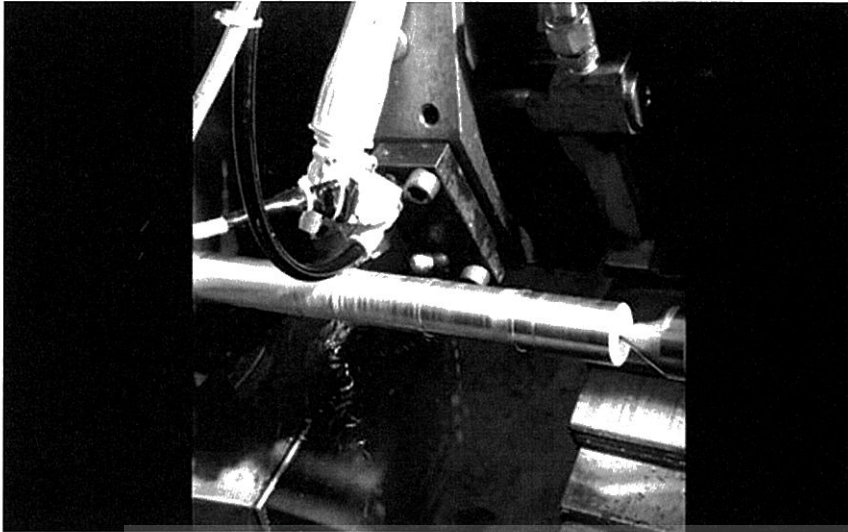
Figure 4.19: How workpiece is placed and clamped

Figure 4.20 (a) and (b) shows the surface roughness condition of the workpiece for 2s and 3s. It had been tested with the stereo microscope for a clear overview of the surface roughness. From Figure 4.20 (a) and (b), the surface roughness of 2s interval time is rougher than 3s. Therefore, the figure is a proof for the assumption that had been stated before. Moreover, the average value of the best surface roughness which is 25s is closed to the average value of the surface roughness flooded supply condition. Then, the workpiece for Experiment 2 is shows in Figure 4.21 (a) and (b).

(a)   (b)
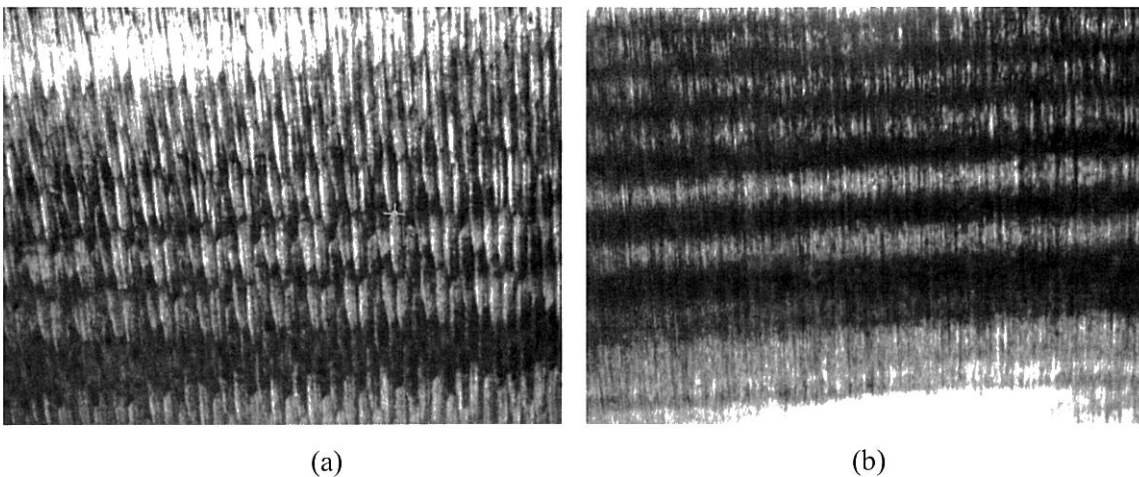
Figure 4.20: (a) Surface roughness for 2s and (b) Surface roughness for 3s

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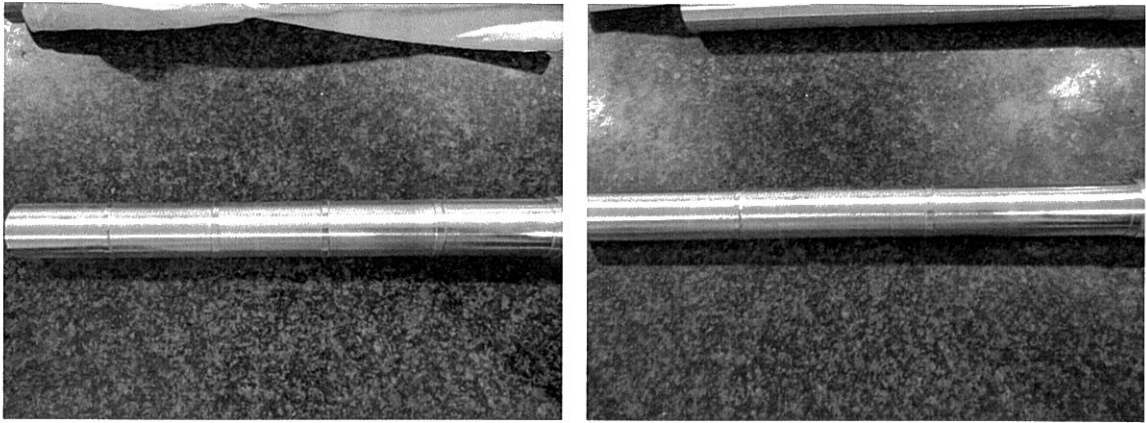
<center>(a)   (b)</center>

<center>Figure 4.21: (a) 2s to 10s workpiece using 100mm cutting length and</center>
<center>(b) 15s to 25s workpiece using 200mm cutting length</center>

4.3.3 Experiment 3 - Interval time 25s to 2s (Descending)

As stated from Experiment 2, 1575rpm cutting speed, 0.04mm/rev feed rate and 1mm depth of cut is used as well as in Experiment 3. In this experiment, the interval time used is inverted from Experiment 2. It will be started from 25s to 2s using a new tool which means the interval time has been arranged to descend. For, 25s, 20s and 15s, the length of the workpiece used is 200mm while for 10s, 5s, 4s, 3s and 2s 100mm of the workpiece is used. The reason for this experiment is to test the effect of a tool on the surface roughness. Then, the result of Table 4.4 is analyse and the best surface roughness is choose based on lowest average value. After that, the result of Experiment 3 is compared with Experiment 2.

4.3.3.1 Experiment 3 Result

Table 4.4 displays the result of the surface roughness for 25s to 2s interval time and Figure 4.22 presents the graph for the surface roughness vs interval time result. The reading is taken 9 times for each run. Then, the average of the surface roughness is calculated to get the best surface roughness of the interval time. From the data of Table 4.4 and Figure 4.22, the best surface roughness that has the lowest value is in the interval time of 20s with 0.263333 average value of the surface roughness

<center>55</center>

Table 4.4: Interval time 25s to 2s result

Time	Average(μm)
25s	0.331111
20s	0.263333
15s	0.353333
10s	0.591111
5s	0.546667
4s	0.448889
3s	0.368889
2s	0.393333
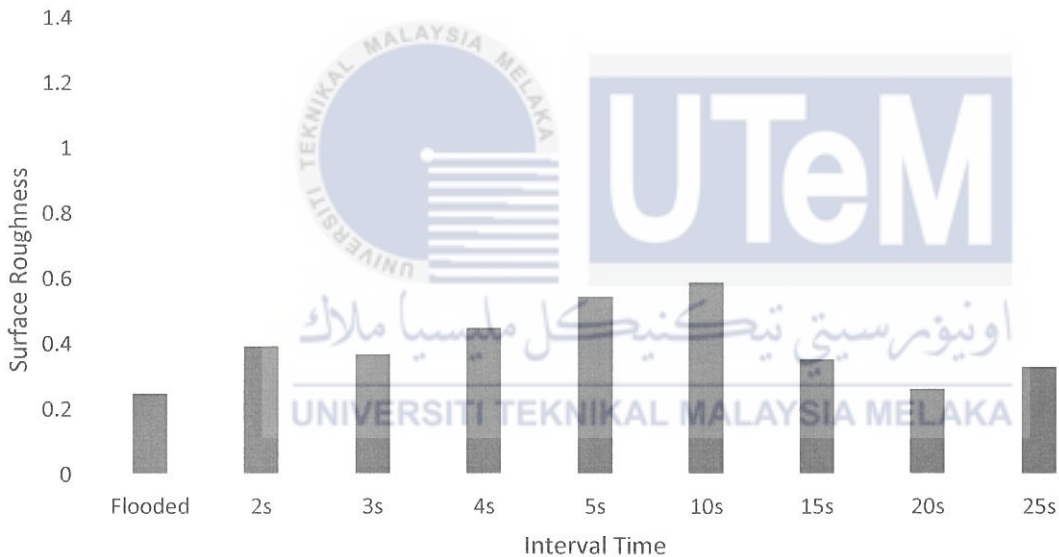
Figure 4.22: Graph surface roughness vs interval time for 25s to 2s

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4.3.3.2 Discussion

According to the graph in Figure 4.22, it is clearly seen that the average result of the surface roughness is reduced a little bit from 2s to 3s and increased greatly from 3s to 10s. On the other hand, the result is reduced again from 10s to 20s and increase slowly in 25s.

Hence, the result of the best surface roughness which is 20s is almost the same as the result of the surface roughness in the flooded supply system.

From the graph depicted in Experiment 2 and Experiment 3, it is shown that the best surface roughness is in 25s and 20s. Experiments 2 is tested from 2s to 25s while Experiment 3 is tested inversely from 25s to 2s. Therefore, it explained the surface roughness value for the for 25s in Experiment 2 and 20s in Experiment 3.

However, the result shows that smoothness of the surface roughness does not affect by a tool since each of Experiment 2 and Experiment 3 is conducted by new tool bit. In Experiment 2 where the experiment is started with the interval time of 2s and end up with 25s, the result shows that with the interval time of 25s, the best roughness is achieved although the tool has been used from the interval time of 2s. Opposite to that, in Experiment 3, the best roughness is achieved at the interval time of 20s where the tool is still in the early stage of the experiment. These results show that the tool condition (wear condition) doesn't gives any effect to the result of the roughness. Figures 4.23, 4.24 and 4.25 show the picture of the tool before and after the experiment while Figure 4.26 (a) and (b) shows the workpiece for Experiment 3. The tool wear is tested under a Stereo Microscope for the clear overview.
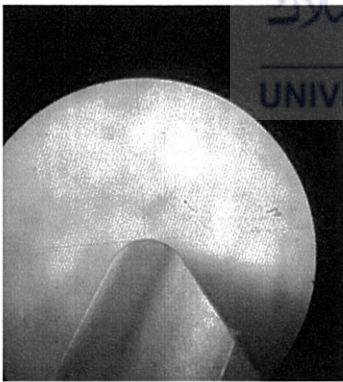
Figure 4.23: Tool bit before experiment   Figure 4.24: Tool bit Experiment 2   Figure 4.25: Tool bit Experiment 3
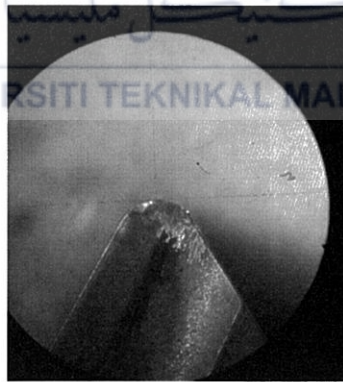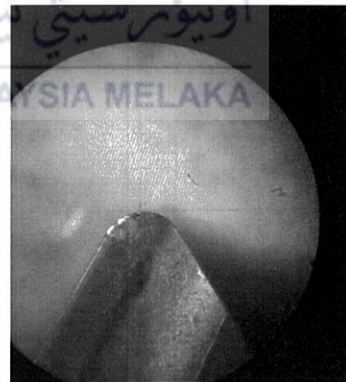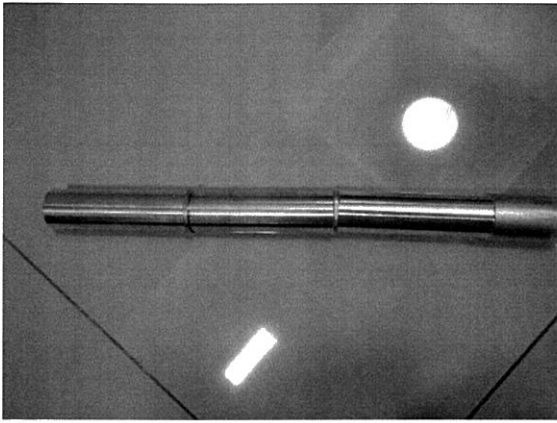
| (a) | (b) |

Figure 4.26: (a) 25s to 15s workpiece using 200mm cutting length and
(b) 10s to 2s workpiece using 100mm cutting length

4.3.4 Effect of Coolant Quantity

Table 4.5: Volume of coolant for Interval Time

Time	Volume of Coolant (ml)
2s	2400
3s	2400
4s	2400
5s	2500
10s	2700
15s	2600
20s	2465
25s	2100

Volume Vs Interval Time
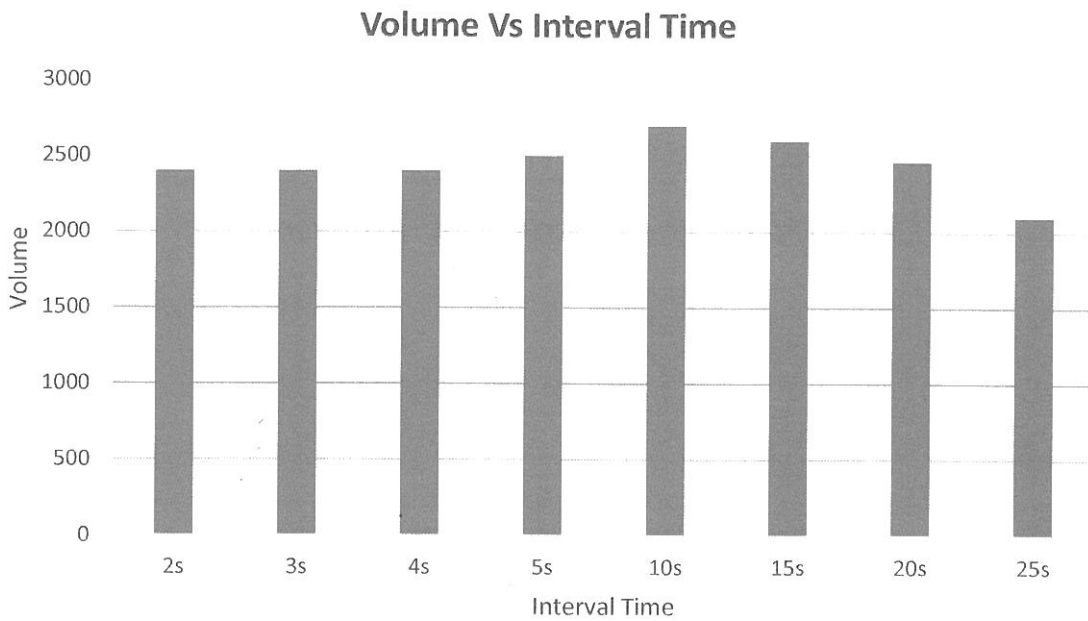
Figure 4.27: Graph coolant volume vs interval time for 2s to 25s

Graph in Figure 4.27 displays the volume of coolant that is used for each interval time in Experiment 2 and Experiment 3. The highest volume of coolant used is in interval time 10s while the lowest is in 25s interval time. This verified the studies that the time-based coolant supply will provide a better surface roughness compared to the conventional cooling method. This method offers favourable effects through reduction of cutting temperature. This situation probably gives effective cooling to the machining zone. Hence, there is a close relationship between the volume of coolant and interval time that give lowest value for the surface roughness.

4.4 Summary

This chapter explained the details about data that had been collected and discussed. Based on the experiments, the used of PLC is able to fulfil the function of the valve operation to control the flow of the coolant. Then, the software and hardware development are successfully built and function. The connection of software, hardware and CNC machine give the best result to the performance of the machine. After that, the workpiece is tested using Mitutoyo surface roughness and the discussion of the data from three difference experiments is explained clearly through the graph and several methods. Hence, relationship

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between surface roughness, tool wear and volume of coolant are then analysed as a proof to the discussion above.

CHAPTER 5

CONCLUSION AND FUTURE WORK

This chapter explained the summary of the project starting from the problem statement, objective, system development and how the experiments are conducted. Results for the 3 experiments are concluded in a summary form. Next, 2 recommendations are suggested for improvement to the system in the future.

5.1 Conclusion

The aim of this project is to produce an automated coolant system on CNC machine that controls the time-period to test the performance of the machine. With the control of time-based, it can reduce the use of coolant that is supplied to the workpiece. Some of the problems that occur in the situation is the increasing of production cost due to the continuous flow of the coolant. The reason is that a large amount of coolant is projected to the workpiece and this produced a lot of waste. Moreover, the use of excessive coolant in an extended period can affect health and environment. Hence, from the journal that had been reviewed, MQL method is chosen to be the referred basis to minimize the use of coolant with the help of PLC to control a time-based coolant supply.

The objectives of this project are stated briefly before starting the experiments. This situation is to ensure that the main purpose of this experiment is clarified so that the objectives can be achieved without any problem. The first objective of this study is to program a Programmable Logic Control for an automated coolant supply system in CNC turning machine while the second objective is to analyse the performance of the automated coolant system in term of surface roughness and tool wear. In order to achieve the first and second objective, a lot of reviewing process had been done. The process of identifying the

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sources such as journals, articles, books and internet helps to identify the problem and collected data. Hence, the materials required and proper method to run the experiment is identified carefully to prevent error.

As stated earlier, the first objective of this study can be completed with the development of hardware and software. The ladder diagram is built with two differences timer in CX-Programmer software. One timer is used to control the opening of the valve while the other timer is used to control the closing of the valve. In the PLC, Omron CPIE is the main device that is used to transmit the command from the software to the valve. The power supply supplied 220V alternative current that converts from AC to DC. In addition, the design of nozzle is printed using a 3D printer with 90mm length and 17mm diameter. It is to connect the nozzle and the valve for the flow of coolant in CNC turning machine. After finished the setup of hardware and software, unloaded load test is performed to test the capability and functionality of the whole system. The test had been done with the interval time of 5s.

Next, 3 experiments are conducted with the used of hardware and software setup. Experiment 1 is designed to obtain the best combination of speed, feed rate and depth of cut while Experiment 2 and Experiment 3 are tested using time-based to control the flow of the coolant. The experiment is analysed to get the best reading of the of the surface roughness and to study the effect of tool wear. The surface roughness of the experiments is measured using Mitutoyo surface roughness tester SJ-310 manual. With the graph and several methods, the discussion of the data from the three difference experiments was explained clearly. From the result, it can be seen that 2s interval time in Experiment 2 has the highest value of the surface roughness. This situation maybe because of some vibration had occurred during the experiment due to the unstable clamped. For the tool wear, the result shows that a smoothness of the surface roughness does not affected by tool since each of Experiment 2 and Experiment 3 is performed using differences tool bit.

As a conclusion, the project is considered prosperously performed since PLC program for an automated coolant supply system in CNC machine is able to be programmed while the objective 2, which is to get the best average value of surface roughness for interval time using PLC program, is achieved.

5.2   Future Work

To further this study, the improvement of the system is suggested to make the system more flexible and practical in operation. Therefore, the following recommendation can be made in future which could be implemented to overcome the problem that might occur. The recommendations are as below.

i.   Increase the distance of the cutting process (workpiece) so that the open and close coolant will be increased. Therefore, the reading of the surface roughness can be taken many times to get the average value of the surface roughness.

ii.   Used the valve that have a small opening. Then, the test can be obtained with the small number of the interval time to get the best reading for the surface roughness.

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APPENDICES

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Title selection	█															
Discussion on problem statement, objective and scope		█	█													
Report writing chapter 1				█	█											
Report writing chapter 3						█	█	█	█	█						
Report writing chapter 2											█	█	█	█		
Log book submission for FYP1											█					
Poster Presentation															█	
Report submission for FYP1																█

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Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Material preparation	█	█	█													
Setup machine				█	█											
Running Experiments						█	█									
Data Collection								█								
Data Analysis								█								
Report writing chapter 4									█	█	█	█	█			
Report writing chapter 5									█	█	█					
Report Editing and Log Book submission											█					
Preparation of Presentation														█		
Final Presentation															█	
Report Submission																█

C Design of Nozzle using SOLIDWORK

TITLE: Part to connect between fitting and solenoid valve

MATERIAL: ABS

DWG NO. Joint

A4

DO NOT SCALE DRAWING

SCALE:1:2 SHEET 1 OF 1
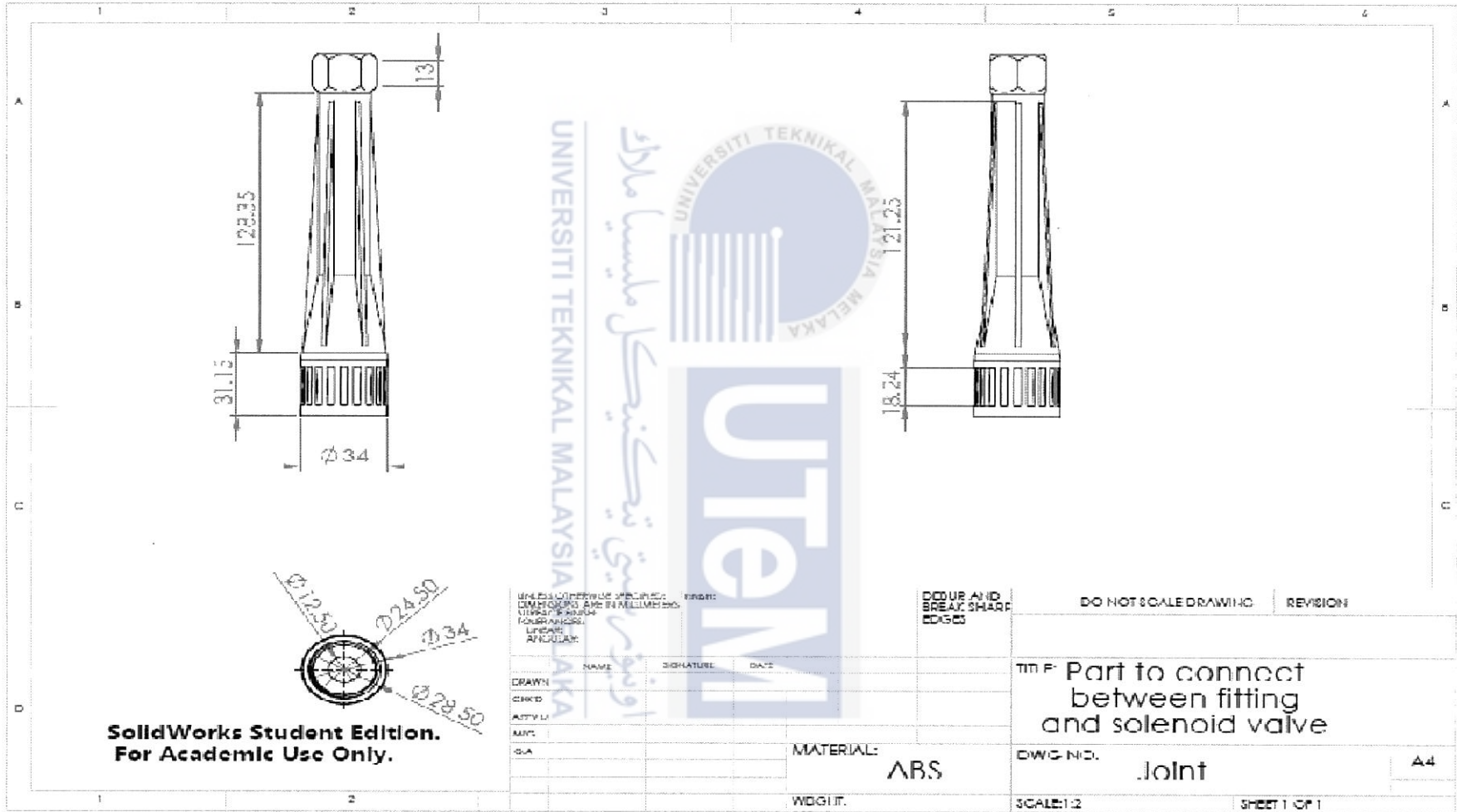
D   Roughness Reading for Test 1

Cutting speed	Feed rate	Doc	1	2	3	4	5	6	7	7	9	Average
1356	0.02	0.5	0.5	0.57	0.68	0.7	0.7	0.6	0.51	0.5	0.61	0.596667
1356	0.04	0.75	0.67	0.71	0.5	0.8	0.49	0.57	0.63	0.53	0.51	0.601111
1356	0.06	1	0.71	0.77	0.63	0.74	0.57	0.67	0.53	0.73	0.63	0.664444
1575	0.02	0.75	0.26	0.37	0.27	0.4	0.41	0.44	0.34	0.37	0.44	0.366667
1575	0.04	1	0.23	0.19	0.35	0.25	0.25	0.29	0.2	0.23	0.25	0.248889
1575	0.06	0.5	0.98	0.62	0.6	0.78	0.84	0.62	0.77	0.76	0.62	0.732222
1785	0.02	1	1.99	3.32	3.17	2.69	4.61	5.27	1.94	3.03	4.06	3.342222
1785	0.04	0.5	2.92	4.63	2.99	3.79	2.8	3.69	3.57	2.23	3.65	3.363333
1785	0.06	0.75	2.22	2.17	3.05	2.67	3.18	3.53	2.82	2.47	2.96	2.785556

E   Roughness Reading for Test 2

Time	1	2	3	4	5	6	7	8	9	Average
2s	1.43	1.09	1.17	1.29	0.98	1.07	1.42	1.09	1.26	1.2
3s	0.43	0.4	0.54	0.49	0.44	0.74	0.39	0.37	0.38	0.464444
4s	0.3	0.42	0.34	0.62	0.34	0.79	0.37	0.35	0.4	0.436667
5s	0.4	0.48	0.34	0.3	0.32	0.35	0.33	0.32	0.27	0.345556
10s	0.34	0.26	0.38	0.32	0.29	0.3	0.26	0.31	0.35	0.312222
15s	0.77	0.91	0.68	0.75	0.71	0.88	0.91	0.86	1.02	0.832222
20s	0.39	0.3	0.39	0.41	0.32	0.29	0.25	0.27	0.26	0.32
25s	0.22	0.33	0.32	0.26	0.28	0.36	0.25	0.28	0.32	0.291111

F   Roughness Reading for Test 3

Time	1	2	3	4	5	6	7	8	9	Average
25s	0.27	0.41	0.29	0.23	0.44	0.3	0.41	0.23	0.4	0.331111
20s	0.17	0.22	0.31	0.19	0.29	0.35	0.21	0.35	0.28	0.263333
15s	0.27	0.31	0.36	0.46	0.29	0.37	0.31	0.28	0.53	0.353333
10s	0.63	0.56	0.54	0.57	0.74	0.7	0.51	0.56	0.51	0.591111
5s	0.38	0.51	0.75	0.43	0.54	0.71	0.61	0.47	0.52	0.546667
4s	0.38	0.56	0.57	0.34	0.36	0.4	0.38	0.63	0.42	0.448889
3s	0.36	0.31	0.4	0.5	0.32	0.43	0.33	0.27	0.4	0.368889
2s	0.38	0.28	0.46	0.36	0.52	0.38	0.45	0.33	0.38	0.393333