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Machinibility Performance of CNC Turning Based on Automated Coolant Supply System

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Abstract**:** ***CNC machine is an industrial manufacturing machine that is used to improve quality and productivity of a product. Good tool life and surface finish of this CNC machining product are produced by applying wet cooling technique. However, this technique had affected the workpiece, tooling, health and environment. Also, there is only 10% to 15% of coolants used from the total amount of supply in the system and this lead to waste and increase productivity cost. Hence, the idea of using Programmable Logic Control (PLC) that inspired the control system of coolant supply plays an important role in developing the modern technology and industry for machining. The purpose is to develop a time-based automated coolant supply system and to test the system performance through evaluation of the roughness of the workpiece surface. The adjusted device to control the coolant supply employed a washing machine inlet control valve. Basically, the used of PLC is able to fulfil the function of the valve operation to control the flow of the coolant through the ON-OFF sequence based on time. Results from the experiment prove that better surface roughness is achieved through the application of automated coolant supply system. Hence, relationship between surface roughness and reduction in consumption of coolant in this system is also obtainable.***

Index Terms**:** ***Automated Coolant Supply, Time-based, Surface Finishing, Turning Machining.***

I. INTRODUCTION

Development of Computer Numerically Controlled (CNC) machine is a tremendous contribution to the manufacturing industries [1]. Although, the performance of the machines allowed high automated control, the increasing of heat due to friction and energy lost can lead the cutter to be unsharpened which can decrease the productivity of the product. Thus, coolant system is necessary as a safeguard to a system from overheating and to remove excess heat at the workpieces. 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 is prevented using the cutting fluid as it is used in the coolant system at CNC machine. It was stated by Courbon et al. [2] 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 [3] that these benefits are diminished by poor health of human operator triggered of the environmentally in compatible coolant. Environmental degradation is another issue.

However, the serious issues about health, environment and economy had been affected by the use of coolant fluids. Based on Sartori et al. [4] whose stated that cutting fluid disposal, components cleaning, pollution and human health damage are some of the problems that affect toward more stringent regulation in order to inspire the application of innovative environment-friendly technologies.

Therefore, to investigate the problems, minimal quantity lubrication (MQL) is used and evaluated regarding the surface roughness, tool wear, temperature deviation, depth of cut and the amount of the coolant system. It is the process of applying minute amounts of high-quality lubricant directly to the cutting tool or workpiece. According to a study, Unist [5] 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 a significant fluid reduction, reduced costs of coolant handling, better cutting tool life, decrease of maintenance as well as increase of machine uptime. Moreover, MQL minimizes environmental impact by reducing fluid usage and decreasing the need for coolant treatment and disposal.

With the details concepts of MQL application, it has sparked the idea of 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 (PLC) for an automated coolant supply system in CNC turning machine as well as to analyse the performance of the automated coolant system in CNC turning machine with regards to surface roughness and tool wear.

II. RELATED WORKS

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.

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CNC machining is a process of manufacturing where the tools and machine are moving based on a programmed of computer software in the CNC machine. Ambrizal et al. [6] claimed that CNC system is built to allow users to perform the motion of tools and parts through numerical data. The process is used to perform a control on the complexity of the CNC machine such as lathes, mills, routhers and grinders. CNC machine performance can be reached using differences parameter including surface roughness, chips formation as well as tool wear.

In other hands, cutting fluid is currently important in performing the CNC machining process since many operations are not able to be efficiently performed without cooling [7]. Cutting fluid is a coolant or lubricant that is produced specifically for metalworking processes. In order to have a good cooling reaction, the cutting area need to be flooded with the cutting fluid in general. In spite of that, cutting fluids also used to help the cutting process in term of smoothing the interface between the chip and the tool's cutting edge. This lubrication also helps to avoid the chips from being sticked onto the tool, in which if this happened then the chips would impeding with subsequent cutting. This supply coolant system is needed to get the desired size control and shape of the workpiece.

The most function of coolant system is to cool and lubricate machines and cutting tools. The cooling of the worpiece is important to remove the heat generated by the friction between tool and workpiece, as well as during the chip formation. The high temperature generated in the region of the tool cutting edge will gives effect to the friction between the chip and the tool during machining and it will affect high power usage and poor in surface finishing. The temperature is also influencing wear rate of the cutting tool. When a cutting fluid supplied coolant or lubricant to a machining process, it helps to reduce the friction levels and thus control the increases in temperature [7]. Fig. 1 shows the area of heat generation that is caused by friction in the cutting zone.

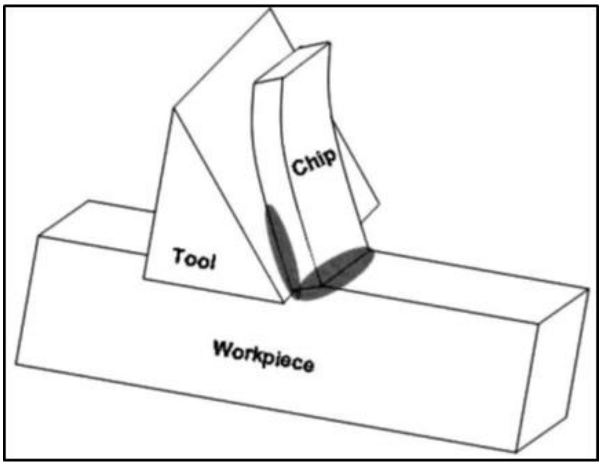

Fig. 1: Heat Generation Area Caused By Friction Of The Cutting Zone [9]

Wet coolant technique is one of the methods to cool down the temperature which also have two functions in both cooling and lubrication process. Elahi et al. [8] 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.

According to Unist [4], 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 difference 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 [9]. 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 accurate result and been used in machining process using tool to define their geometry.

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. [10] statement that the goal of MQL technique is to minimize the amount of cutting fluid applied in the machining process. According to Unist [4] to gain the successful implementation of MQL, the presence of lubricant is needed between the cutting edge and the workpiece. In other hand, Tai et al. [11], stated that the basic research in turning, milling, and drilling of CNC machining had proved that MQL is able to perform the same performance or sometimes even better than the wet condition in the processes of cutting.

However, the main disadvantages of the MQL method is that it is not able to cool the cutting surface. This shows that MQL is not really effective if it is used in a cutting operation that is required to have a cooling action[12]. Nonetheless, wet cooling machining also posses some disadvantages compared to MQL machining, for example wet cooling technique produce higher cost and potential safety hazards. Therefore, the amount volume of coolants that supplied to decrease the temperature of tool wear and workpiece, as well as the time interval, need to be controlled to reduce waste and production cost while at the same time produce or maintain a good quality of surface for the workpiece.

Hence, a previous research on PLC controller is taken as an evidence for the sustainability of controller to control the coolants that will be supplied to the workpiece. According to Dumitru et al. [13], 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 [14] that the achievement of PLC can be divided into two which are development system and running system, and it is used as a core of the soft PLC, run the program and to process the input and output. Furthermore, it was claimed by Ergenc and Koca [15] that PLC has real-time operating systems, timers and counter essential for real-time control systems and relatively control application for economical resolutions.

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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.

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.

III. METHODOLOGY

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 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.

A. Hardware Setup

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 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.

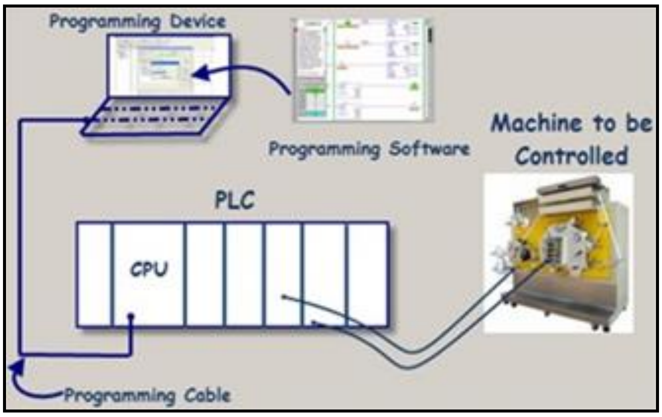

Fig. 2: Diagram of the system

B. Experimental Setup

Lastly, the overall system to run the experiments is setup to a turning machine. This experiment conducted in Haas SL-20 CNC Turning Machine with the aluminium type of workpiece as shown in Fig. 3. 30 mm diameter of workpiece with 100mm and 200mm distance of cutting process is used to get the best interval time in term of surface roughness as well as tool wear. The combination of 1575 rpm cutting speed, 0.04mm/rev feed rate and 1mm depth of cut are used to get the exact data needed in this experiment with 8 difference interval times.

Fig. 3: The Experimental Platform

IV. RESULT AND DISCUSSION

Fig. 4 and 5 show the results of the turning process operated on the aluminium workpiece. Each interval time period is running for one cutting and labelled with a black marker pen. After all cuttings are done, the surface roughness of the cutting surface is measured by using a roughness tester and the result is shown in Table 1 as well as in the graph of Fig. 6. For each 2s, 3s, 4s, 5s and 10s interval time the length of the workpiece is 100mm while for 15s, 20s and 25s interval time, 200mm of the workpiece is used.

Fig. 4: 2s To 10s Workpiece Using 100mm Cutting Length

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Fig. 5: 15s To 25s Workpiece Using 200mm Cutting Length

Table 1: Result Of Interval Time Vs Surface Roughness

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

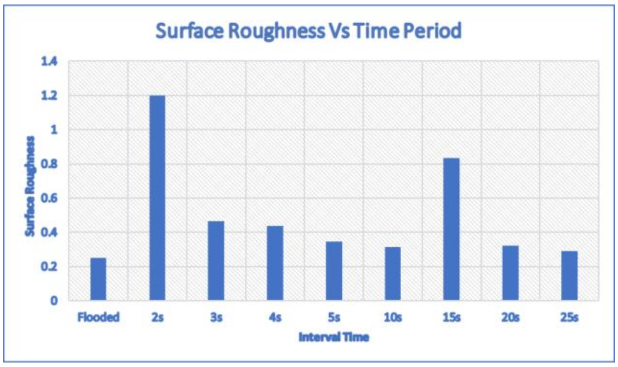

Fig. 6: Graph of Surface roughness vs Interval time

A sudden increment in the surface result during the interval time of 2s can be seen in the graph of Fig. 6. Supposing that this situation did not happen except for a technical problem. This is probably because some vibration had occurred during the experiment for interval time of 2s due to the unstable clamped. It happens since that 2s was the first run conducted in the experiment. From Fig. 7 and 8, the surface roughness of 2s interval time can be seen rougher than the one obtained for 3s interval time. Therefore, the images are the proof for the assumption that had been stated before. A similar phenomenon can be seen occurring in the surface result of 15s interval time. Further investigation need to be conducted to find the actual cause for a rougher surface result obtained during the mentioned interval time. It was totally out of expectation as the surface results were seen to be stably reducing from interval time of 3s to 10s before increase all of a sudden. One of the expected reasons is that the clamping condition of the workpiece, similar as the previous explanation for the surface result of 2s interval time. Vibration could be the main reason due to unproper clamping condition.

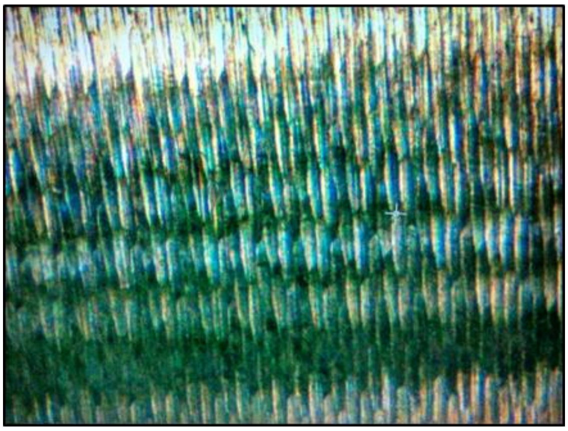

Fig. 7: Surface Roughness Of Workpiece Undergone Turning In 2s Interval Time

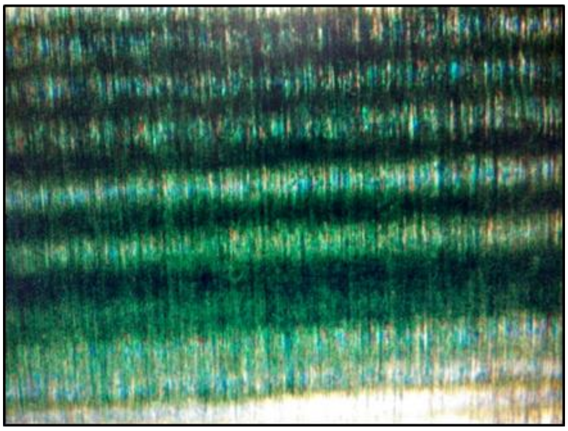

Fig. 8: Surface Roughness Of Workpiece Undergone Turning In 3s Interval Time

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.

V. CONCLUSION

The aim of this project is to evaluate the performance of a CNC machine under coolant supply of a proposed automated coolant system that controls time-period of the coolant supply. With the control of time-based, it can reduce the usage amount of coolant supplied to the workpiece. As discussed in the eraly stage of this paper, currently there are a few techniques that are used for the coolant supply of CNC machine. But those techniques posses some disadvantages.

One of the problems that occur in the previous techniques is the increasing of production cost due to the continuous flow of the coolant.

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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.

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, which is to get the best average value of surface roughness for interval time using PLC program, is achieved.

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Wan Nur 'Izzati Wan Md Hatta received her B.Eng in Manufacturing Engineering form the Universiti Teknikal Malaysia Melaka, majoring in Robotics and Automation. She produced a tremendously successful project in developing a new time-based automated coolant supply system for CNC turning machine for her final year project. She is currently her study in Master Degree at the Graduate School of Engineering, Universiti Teknikal Malaysia Melaka, Malaysia.

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