Faculty of Manufacturing Engineering

DEVELOPMENT OF AUTOMATED COOLANT SUPPLY (ACS) SYSTEM IN IMPROVING CUTTING PERFORMANCE FOR CNC MILLING MACHINING

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Master of Manufacturing Engineering
(Quality System Engineering)

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in fulfillment of the requirements for the Master of Manufacturing Engineering
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DECLARATION

I declare that this thesis entitled "Development of Automated Coolant Supply (ACS) System in Improving Cutting Performance for CNC Milling Machining" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : WAN NUR 'IZZATI BINTI WAN MD HATTA

Date : 6 SEPTEMBER 2019

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Quality SystemEngineering).

Signature	:	.....
Supervisor Name	:	DR FAIRUL AZNI BIN JAFAR
Date	:	6 SEPTEMBER 2019

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, Dr. Fairul Azni bin Jafar, 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.

ABSTRACT

CNC machine is an industrial manufacturing machine that is used to improve quality and productivity of product. There are two ways of applying coolant in general, which are dry machining and wet cooling machining. Therefore, some researches had been done in order to get information about the method involved. It had been found that there are some disadvantages for both techniques and this had bring differents result to the workpiece, tooling, health and also environment. Moreover, the used of wet cooling technique causes waste since the workpiece only need a small amount of coolant. Then, increase in temperaturedue to the friction and energy lost can lead the cutter to be unsharpened and it will affect high power usage and poor in surface finishing. Hence, the idea of using PLC that inspired as the control system plays the main role in developing the modern technology and industry. The purpose of this project is to design an Automated Coolant Supply (ACS) System based on Programmable Logic Control for CNC milling machine, to identify the best interval time for the performance of the proposed Automated Coolant Supply (ACS) System and to analyse angle positioning and nozzle distance of 3 difference types of nozzle in the CNC machining under Automated Coolant Supply (ACS) System.The structure of this project involved development in software and hardware. Then, the adjusted timer to control the coolant supply is by applying the washing machine inlet to control valve. Three experiments involved in this study which are Experiment 1 started by finding the best combination of parameters using Taguchi method. Then, Experiment 2 is testing the performance of the machine by using 1s to 60s interval time. After the best interval time for the surface roughness had been investigated, 3 differences shape of nozzle with 8 difference positions of nozzle and 7 distances of nozzle are used to run Experiment 3. Performance involve the study in shape and position of nozzle are analysed in order to measure the relationship of nozzle criteria force. It had been found that this ACS method is succesful since interval time 25s has the best surface roughness value with the lowest quantity of coolant used. The data and graph could be seen in Experiment 2 results. Meanwhile, it is supported by using 3 differences shape of nozzle. All of the shapes, angles and distances of nozzle involved give various results. Hence, it can be concluded that this ACS system is successful and it is recommended to be used in future.

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 kaedah-kaedah yang terlibat. Di dalam kajian ini, didapati bahawa terdapat kelemahan untuk kedua-dua teknik tersebut yang memberi kesan terhadap bahan kerja, peralatan yang digunakan, kesihatan, serta alam sekitar.Selain itu, kegunaan teknik penyejukan basah akan menyebabkan pembaziran kerana bahan kerja hanya memerlukan sedikit penyejuk. Seterusnya, peningkatan suhu disebabkangeseran dan kekurangan tenaga boleh menyebabkanmata alat menjadi tumpul dan ia akan memberi kesan kepada penggunaan tenaga elektrik dan permukaan akhir 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 menghasilkan sistem 'Automated Coolant Supply (ACS)' menggunakan 'Programmable Logic Control (PLC)' untuk mesin milling CNC, untuk mengenal pastiselang masa yang terbaik dengan kegunaan'Automated Coolant Supply (ACS)' dan untuk menganalisalokasi dan jarak 3 jenis muncung yang berbeza di dalam mesin milling CNC menggunakan sistem'Automated Coolant Supply (ACS)'. Selain itu, struktur projek ini melibatkan penyediaan 'software' dan 'hardware'.Masa diselaras untuk mengawal pengeluaran cecair bagi menyejukkan bahan kerja dan mata alat menggunakan inlet mesin basuh untuk mengawal injap. Tiga eksperimen yang terlibat dalam kajian ini ialah Eksperimen 1 bermula dengan mendapatkan kombinasi parameter yang terbaik menggunakan kaedah Taguchi. Kemudian, Eksperimen 2 bagi menguji prestasi mesin dengan menggunakan selang masa 1s untuk 60s. Selepas selang masa yang terbaik untukpermukaan akhir telah dianalisa, 3 jenis bentuk muncung dengan 8 lokasi dan 7 jarak muncung yang berbeza telah digunakan untuk menjalankan Eksperimen 3. Prestasi melibatkan kajian bentuk dan posisi muncung telahdianalisabagi mendapatkan hubungan kriteria muncung tersebut. Didapati bahawa kaedah 'ACS' ini telah berjaya memandangkan selang masa 25s mempunyai permukaan akhir yang tebaik dengan menggunakan kuantiti penyejuk yang paling sedikit. Data dan graf dapat dilihat dalam keputusan Eksperimen2. Tambahan lagi, ia disokong dengan menggunakan 3 bentuk muncung yang berbeza. Semua bentuk, posisi dan jarak muncung yang terlibat telah menghasilkan keputusan yang perbagai. Oleh itu, ini disimpulkan bahawa sistem ACS berjaya dan adalah disyorkan untuk digunakannya pada masa hadepan.

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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 xii
ACS	-	Automated Coolant Supply

LIST OF SYMBOLS

%	-	Percent
mpa	-	Mega pascal
m/min	-	Meter per minute
mm	-	Milimeter
mm/s	-	Milimeter per second
mm/min	-	Milimeter per minute
rpm	-	Revolution per minute
μm	-	Micrometer
ml	-	Mililiter
ra	-	Roughness average
C	-	Circular
R1	-	Rectangular 1
R2	-	Rectangular 2
F	-	Force
N	-	Newton
λc	-	Cut-off length
Λs	-	Low-pass filtering
Φ	-	Angle
°	-	Degree
s	-	Second

LIST OF PUBLICATION

1. Wan Nur ‘Izzati Wan Md Hatta, Fairul Azni Jafar, Farizan Mohd Nor, Ahamad Zaki Mohamed Noor, 2019. Machinibility Performance of CNC Turning Based on Automated Coolant Supply System. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 8(10), pp 3953-3957.

CHAPTER 1

INTRODUCTION

The overview of this chapter explains about the importance of coolant system in Computer Numerical Control (CNC) machine, the cleaner application software and a method to be applied in the coolants system. Then, the used of PLC is explained in order to replace the conventional method. Next, application of various shapes and positions of nozzle is investigated to identify the performance of CNC milling machine with the help of Automated Coolant Supply System. Lastly, the problem statement, objectives and scopes are discussed.

1.1 Background

Ansar *et al*., (2016) stated that to increase the flexibility of the machine in handling 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. 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. According to Dhar and 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.

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.

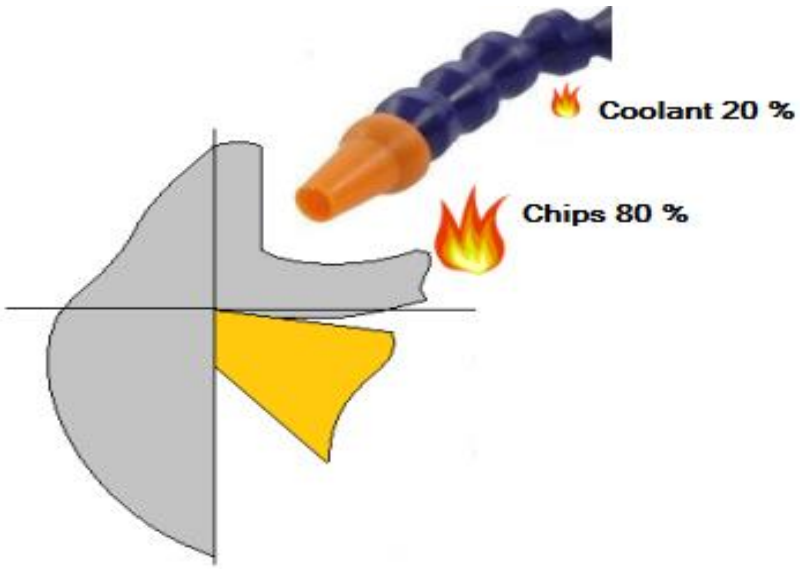

Figure 1.1: Percentage of the heat generated (Source: http://cadem.com/cncetc/cnc-machining-coolant/)

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 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. Moreover, MQL minimizes environmental impact by reducing fluid usage and decreasing the need for coolant treatment and disposal.

With the detail 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. Therefore, the aim of this project is to design an Automated Coolant Supply system based on PLC for CNC milling machine. This is due to the concept of PLC that can control the whole system and also the application will reduce operation cost as well as energy consumption (Debnath, 2018).

Related to the PLC program practice, the action in designing nozzle system is proposed to be done by identifying the effect of shape and position to the surface quality and cutting performance in CNC Milling Automated Coolant Supply system. This is because, the used of nozzle in different industries give may give results in the performance of machine due to type of fluid flowing and fluid flow action through nozzles (Singh *et al.*, 2019).

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 coolant to cool down the temperature of the tool and workpiece. Moreover, 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, ~~a~~ research had been done before using the idea of MQL method with the help of PLC. The time-based coolant supply is developed to increase the recycle lengthen of the coolant while it will reduce the cost. Then, from the continuous review it had found that the nozzle position and shape also affect the performance on CNC milling machine. Therefore, a lot of research works need to be implemented to study the interval time that give the best value of the surface roughness and also criteria of nozzle that affect the machine performance.

1.3 Problem statement

Basically, conventional of CNC machines use wet cooling method to reduce heat and excess chips at the workpiece. However, in this study there are three major problems that exist when the wet cooling method is applied. Firstly, large amount of fluid is being projected to the workpiece and this produces a lot of waste since the workpiece only need a small amount of coolant. This factor shortens the time for the coolant to be recycled. Moreover, the use of excessive coolant in an extended period can affect health and environment. It is due to the used of wet and mist coolant technique that can give bad influences on the environments and waste disposal. Furthermore, the used of other method such as dry technique increased friction adhesion between tools and workpiece and it effect the temperature. 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. Meanwhile, MQL machining provides an economically and ecologically reasonable alternative to the coolant technique. Therefore, MQL inspired method, the development of PLC to control time-based coolant supply and a few types of nozzle shapes and positions is proposed to minimize the problem.

1.4 Research questions

The research questions of the project are as follows:

i. What method or program should be used to design an Automated Coolant Supply (ACS) System to control the coolant flow in CNC milling machine in order to reduce waste?

ii. Does the interval time effect the surface quality and cutting performance for tool life and workpiece in CNC Milling Automated Coolant Supply (ACS) System?

iii. How does difference positions and shapes of nozzle in Automated Coolant Supply (ACS) System improve the performance of tool life and workpiece in CNC milling machine?

1.5 Research hypothesis

The research hypothesis of the project are as follows:

i. The productivity cost can be reduced by using Programmable Logic Control (PLC) program without interfere the product quality and safety. Supporting by Ergenc and Koca (2014) stated that PLC is a program used to have real time operating systems, timers and counter crucial for real time control systems and comparable application to control economical resolutions.

ii. 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. Moreover, Tai *et al.*, (2014) stated that it will reduce the flexibility to replace the machine, minimizing the waste stream, minimize the floor space to get clean and healthier work environment. Hence, the used differences interval time does affect the surface quality and cutting performance for tool life and workpiece.

iii. Various shapes and positions of nozzle affect the performance of tool life and workpiece. This is due to the increasing spraying angle and excess mist that give low fluid particle pressure when longer distance are used between the nozzle and tool (Mulyadi, 2013). Therefore, nozzle is arranged in specific positions with differences angle and distance to allow evaluation of the fluid trapping effect and to avoid obstruction of chip formation.

1.6 Objective

The objective of the project are as follows:

i. To design an Automated Coolant Supply (ACS) System based on Programmable Logic Control for CNC milling machine.
ii. To identify the best interval time for the performance of the proposed Automated Coolant Supply (ACS) System.
iii. To analyse angle positioning and nozzle distance of 3 difference types of nozzle in the CNC machining under Automated Coolant Supply (ACS) System.

1.7 Scope of the research

The scope of the project are as follows:

i. Using CNC milling machine.
ii. Using Omron CP1E to program the PLC.
iii. CNC Laboratory room as a workplace to do the experiments.
iv. Workpiece is AISI 304L only, other types of workpiece material is not considered.
v. The cutting fluid used is Al Soluble Extra and other types of cutting fluid is not considered.
vi. Using 3 shapes of nozzle with different position to supply the coolant.