ENHANCED AUTOMATED COOLANT SUPPLY SYSTEM FOR CNC MACHINING

Submitted in accordance with the requirement of University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons)

by

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APPROVAL

This report 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:

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(Dr. Fairul Azni bin Jafar)

ABSTRAK

Cecair pemotongan adalah sejenis penyejuk dan pelincir yang direka khususnya untuk proses pemesinan. Teknik penyejukan basah adalah salah satu sistem bekalan penyejuk,dimana jumlah penyejukan terus dibekalkan kepada bahan dan alat pemotong semasa pemesinan. Peningkatan tempoh pergunaan alat dan kekasaran permukaan dikenalpasti apabila teknik penyejukan basah digunakan. Sebaliknya, ia akan membawa kos penyelenggaraan yang tinggi serta kesan negatif kepada alam sekitar dan pekerja. Oleh itu, sistem penyejuk automatik yang dipertingkatkan untuk pemesinan CNC telah mengurangkan jumlah penyejuk yang digunakan. Sistem bekalan penyejuk yang berasaskan masa telah berjaya dibina dan diuji. Penerima terdiri daripada suis, injap kawalan aliran dan geganti. Mikrokontroller Arduino UNO digunakan untuk mengawal geganti yang dipasangkan manakala suis dihidupkan sebelum pemesinan bermula. Relay mengesan isyarat yang diterima daripada mikrokontroler Arduino dan hidup/ mati mengikut program yang ditetapkan. Terdapat dua ujian yang penting antara satu adalah mencari parameter yang berkualiti terbaik melalui cara 'Taguchi'. Selapas itu, ujian yang seterusnya ialah menggunakan parameter yang terdapat daripada ujian dahulu dan menjalankan dengan sistem berdasarkan masa daripada sesaad sehingga 60 saad. Ujian kekasaran permukaan diuji melalui penguji kekasaran selepas ujian pemotongan dengan sistem permasaan. Selang masa terbaik untuk membekalkan dan menghentikan penyejuk adalah 30 saad dengan nilai kekasaran permukaan 0.773 μm dengan menggunakan kelajuan gelendong 1200 rpm, laju suapan 100 mm / min dan kedalaman pemotongan 0.4 mm. Sistem ini sangat berguna untuk semua kaedah banjir tradisional. Ia memastikan produk yang berkualiti, mengurangkan penggunaan penyejuk serta peningkatan tempoh pengunaan alat.

ABSTRACT

Cutting fluid is a type of coolant and lubricant designed specifically for machining processes, such as milling and turning. The wet cooling technique is one of the coolant supply system, where a large amount of coolant is supplied directly to the workpiece and cutting tool during machining. An increase of tool life and surface roughness can be achieved by using the wet cooling technique. However, it will bring high maintenance cost, negative impact to the environment and operator. Thus, an automated coolant supply system for CNC machining is developed with some enhancement compared to the previous prototype to reduce the amount of coolant used. Time-based coolant supply system had been successfully constructed and tested. The nozzle connect with switch, valve and relay. An Arduino UNO microcontroller is used to control the relay. The switch is switched ON before the machining start. Then, the relay detects the signal received from the Arduino microcontroller and ON/OFF according to the pre-programmed. Two major experiments are carried out. One of the experiments is found the best combination of parameter that obtained from Taguchi method with unloaded coolant. Another experiment is using the best parameter run with the system by increasing the time interval from 1 second until 60 seconds. After the machining is done, the surface roughness testing based on the system is identified though the surface roughness tester. The best time interval for supplying and stop supplying the coolant is 30 seconds with the surface roughness value of 0.773 μm using with the spindle speed of 1200 rpm, feed rate of 100 mm/min and depth of cut of 0.4 mm. This system is extremely useful for all traditional flooding method. It ensures products with a better quality, reduction in consumption of coolant in this development system and increased tool life.

DEDICATION

Only

my beloved father, Tan Kong Yew

my appreciated mother, Tey Kim Lian

my adorable brother and sisters,

Tan Rou Hui

Tan Jing

Tan Rou Yi

my appreciated project supervisor, Dr. Fairul Azni bin Jafar

my supportive friends,

For giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CNC	-	Computer Numerical Control
FKP	-	Faculty of Manufacturing Engineering
ISO	-	International Organization for Standardization
LED	-	Light-emitting Diode
MIT	-	Massachusetts Institute of Technology
MQL	-	Minimal Quality Lubrication
NC	-	Numerical Control
NPT	-	National Pipe Taper
PCB	-	Printed Circuit Board
PLC	-	Programmable Logic Controller
STL	-	Standard Template Library

LIST OF SYMBOLS

°C	-	Degree Celsius
h	-	Hour
km	-	Kilo Meter
KPa	-	Kilo Pascal
l	-	Liter
min	-	Minute
ml	-	Milliliter
mm	-	Millimeter
MPa	-	Mega Pascal
RM	-	Ringgit Malaysia
s	-	Second
µm	-	Micro Meter
°	-	Degree
Ra	-	Surface Roughness
V	-	Voltage
rpm	-	Revolution per Min
Ω	-	Ohm

CHAPTER 1
INTRODUCTION

This chapter is the idea of the Final Year Project. “Enhanced Automated Coolant Supply System for CNC Machining” which is a project that involved in design and develop a new coolant supply technique using the idea of time-based and refer to the ideal coolant supply system today. The background, motivation, problem statement, objective, scope and report structure will be explained in this chapter.

1.1 Background

CNC milling machine is the machine that removes material in the form of small chips through drilling to create the desired shape and wisely introduce into the manufacturing environment. Milling is the process that moving the cutting tool towards the workpiece and remove the material by control the cutting feed, cutting speed, spindle speed, feed rate, axial depth of cut and radial depth of cut. For manufacturer, they are always seeking for high quality and high efficiency, product with the lowest production cost in order to increase their profit.

However, the lifetime of a cutting tool cannot be ignored because any damage on the cutting tool will causes the catastrophic failure. Besides, the tool life is affected by the material of

cutting tools and cutting parameters such as cutting feed, and the total cut time. During the moment of removing unnecessary material, it will generate heat energy to the cutting tool and on the workpiece and indirectly it will affect the chemical and physical properties of the workpiece. Ezugwu and Wang (1997) claimed that titanium machining will conduct about 80.15 % of the heat into the tool, while this proportion is only 50.45 % when machining steel. It has also resulted that a high temperature concentrated on the cutting area and indirectly the bonding strength of the tool and workpiece became weak, and thus accelerates the tool wear.

Todays, there are different types of cutting fluid that commonly used for CNC machine which are straights oils, soluble oils, semisynthetic fluids and synthetic fluids. The cutting fluid can have the similar effect or more efficiency compared with the pausing production, which is achieved low energy consumption in a low friction situation about 7.5 %, saving in manpower about 0.13 %, saving the maintenance or replace tools costs about 20 % and savings the indirect cost which that is dependent on downtime factors. Bannister (1996) stated that a lubricant basically having the functions of reducing the friction, reduce tool wear, absorbing the shock, reducing the tool and workpiece temperature, minimize corrosion and seal out contaminants.

However, those cutting fluids have very strong negative impacts to environment and health. Shashidhara and Jayaram (2010) stated that frequent use of petroleum based oils will create a lot of negative effects on the environment. A special required of physical and chemical treatment needed to be taking action in order to withdraw the toxic components from cutting fluid before disposal. Inappropriate storage and disposal ways which will bring an unpredictable negative impact on the environment and results in pollution of surface water and groundwater, air pollution, soil pollution and then agricultural product and food pollution. Thus, it is categorized as a hazardous waste to biological life and the environment.

Cetin *et al.* (2011) also stated that during cutting fluids vaporize and spread into micro particles. Dermatological as well as inherent diseases, lung cancer, genetic diseases and respiratory infections might become a serious issue and health problems to the operator. Debnath *et al.* (2014)

also mentioned that the cost of cutting fluids cannot remove from the budget, but we can reduce the usage of cutting fluids and indirectly reduce the cost.

Since health issues, environmental issues and economic issues had been discussed among the manufacturer. Thus, various method of application of cutting fluids in CNC machine had been investigated and developed in order to minimize or replacement of cutting fluids which are dry machining, conventional flood lubrication (Wet Cooling) and minimal quantity lubrication (MQL). Those cooling techniques are developed through investigating regarding to the surface roughness, tool wear, temperature deviation and amount of coolant used. Todays, these common types of cooling technique are shown in below.

a) Dry Machining

Dry machining is a machining process that doesn't involved any coolant application during CNC milling or drilling. Dry machining is achieved by controlling the machine speed and the carbide technology. In order to protect the cutting tool, a carbide substrate is developed. This coated tool plays the role of the heat shield between the carbide substrate and the hot chip during machining. The tools are becoming tougher due to the characteristics of the carbide element and reduce the tool wear. The dry machining is suitable for milling, but not suitable for turning. In turning process, it is controlling the workpiece and the workpiece is rotated at high speed and extra tool wear needed. Steels, cast iron and come stainless materials are the primary choice for cutting those materials. The three major advantage of dry machining has extended tool life by removing the thermal shock cycle, remove the cost of coolant and away from the negative impact bring to the operator health.

b) Conventional Fluid Lubrication (Wet Cooling)

The conventional fluid lubrication process is the most common application method that delivers a steady flow of cutting fluids to the cutting tool which results in the reduction of heat, removing the chip away from the workpiece and provides lubrication to avoid

corrosion. Using conventional flood lubrication will result in a poor surface roughness of the workpiece due to over or large amounts of coolant directly supply on the workpiece surface and giving extra force to the workpiece. The key wear mechanism for flood cutting were diffusion, abrasion and micro-chipping. There is an unnecessary waste of cutting fluids which lead to a high production cost.

c) Minimal Quantity Lubrication (MQL)

Minimal quantity lubrication is the process that applying minimum amounts of high quality cutting fluids to the cutting tools or the workpiece interface. MQL helped to minimize the environmental impact by reduce the usage of fluid significantly and eliminate the problem of disposal and coolant treatment. The major advantages of MQL are reducing the cutting fluid consumption, produce the dry chips which ready to be recycled, improved the part quality and most important is solve the negative impact to environments.

After comparison with these three cooling techniques, the concepts of MQL applications have been chosen as the basic reference for this development project. This is because the MQL achieved in machining performance, cost reduction from the success of minimum coolant needed, minimizing the machine- tool clean cycle time and usage of energy. From the concept of those cooling techniques, an idea on using time-based supply coolant with the help of Arduino microcontroller is inspired.

The goal of this project is to develop an automated coolant supply system with the help of the Arduino microcontroller to control the amount and the timing of the coolant needed. By using this technique, it is expected the surface roughness of the cutting area achieve the similar or better compared to the current conventional flood cooling technique, tool wear lifetime is reduced, and more environmental friendly to user.

1.2 Motivation

It is believed that the only small amount of coolant play role in the cooling system application. Sun *et al.* (2006) found that the coolant is not performing its function at the speed of 100m/min using the same method between three various types of coolant system with constant 0.5mm of axial depth of cut, 2mm of radial depth of cut and 0.1 mm/tooth of the feed rate.

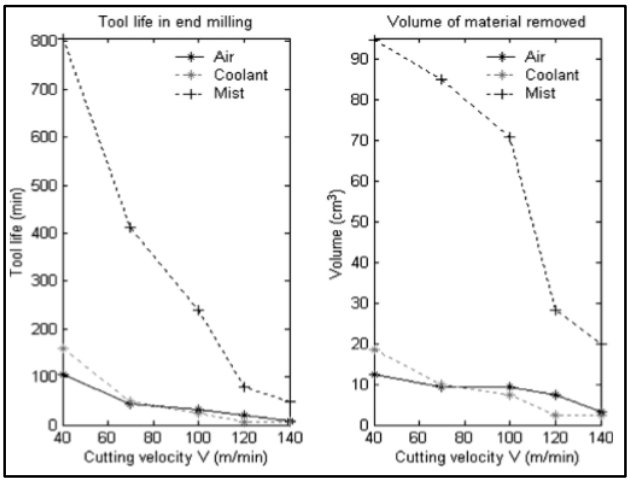

Figure 1.1: Tool life under varied cutting speed in three coolant supply method.

Whiles, the other amount of coolant supply is a waste. Thus, big amount of the coolant has directly increased the cost and shorten the period of coolant. Due to the disadvantage now's cooling system, it is believed that by controlling the amount of coolant supply and time to supply coolant could increase the period of replacing coolant by using an Arduino to develop a system.

1.3 Problem Statement

Nowadays, most of the conventional CNC machines are using flood cooling method to eliminate the friction between cutting tools and workpiece and causes reduction in heat of the cutting area and rinse away the chips. However, there are three major existing problems with the used of wet cooling method. Admittedly, high usage of coolant which increases the frequency of replacement of coolant in CNC milling machine and high maintenance cost. Furness *et al*. (2006) stated that over five millions gallons which conducted at several powertrain plants is identified within Ford Motor Company for annual coolant usage and costing several million of US dollars. Dudzinski *et al.* (2003) claimed that the using the coolant will bring high additional costs. Lastly, it will bring negative impact to the environment and operator. Dudzinski *et al.* (2003) stated that the use of cutting fluid is undesirable for the healthiness of human, surroundings such as disposal problem. This is because of the cutting fluid will evaporate during machining and these chemical substances can easily approach our skin causes skin diseases. Besides, the cutting fluid needs an extra cost for disposal to avoid environment pollution.

1.4 Objective

The objective of this project are:

i. To develop an automated coolant supply system which suitable for CNC milling machine by using an Arduino microcontroller to control the timing supply the coolant.

ii. To analyze the performance of the system.

1.5 Scope

The scope of this project are:

i. Arduino is used to control the new system.

ii. 10 mm high speed steel tooling is installed.

iii. AI Soluble Extra is the cutting fluid which used in this system.

iv. Material of workpiece is made from aluminium.

1.6 Report Structure

This report consists of five main chapters which consists of introduction, literature review, methodology, discussion and conclusion. There is some information and review are discussed after this. First of all, the whole report information is discussed in chapter 1. Which included the project background, motivation, problem statement, objective and scope.

In chapter 2, the literature review is involved in some information from internet resources and a lot of researches which related to the CNC machine, different cooling technique and automated supply system. First of all, it discussed the history and benefits of CNC machine. All five cooling technique is discussed which related to the results of the experiment done by another researcher, benefits of different cooling techniques and compared between all five cooling techniques and thus MQL has been selected as the basic guideline for this project. Besides, the benefits and the applications of PLC and Arduino microcontroller are listed. Lastly, the Arduino microcontroller had been chosen for using to success this project.

In chapter 3, methodology is the key to success the objective and scope of this project. Every method will affect the final result of this project. The overall process flow chart is elaborate about the project flow. Bill of materials had been listed out and designed of the joint part is

discussed in the next two chapters. Besides, all experiment procedure to verify the performance had been covered.

Next, chapter 4 contains of hardware and software development. For the hardware development, the specific particulars about the connection of mechanical and electrical parts are covered. For the software development, the coding used will be explained. Experiment of 9 combinations of parameter with unloaded coolant are carried out and experiment of time based coolant supply system are covered and the performance of those experiments are also covered.

Lastly, chapter 5 concludes the objectives achieved by this project and also summarize the outcomes of the testing. Besides, the recommendations for the future works are listed.