INVESTIGATION ON CNC TURNING PARAMETERS BY USING A VORTEX TUBE COOLING SYSTEM

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

by

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FACULTY OF MANUFACTURING ENGINEERING

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **INVESTIGATION ON CNC TURNING PARAMETERS BY USING A VORTEX TUBE COOLING SYSTEM**

Sesi Pengajian: **2017/2018 Semester 2**

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Engineering) (Hons.). The members of the supervisory committee are as follow:

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(Mr. Mohd. Fairuz bin Dimin @ Mohd. Amin)

ABSTRAK

Proses melarik CNC adalah sebahagian daripada proses pembuangan bahan yang bertujuan untuk mengubah dimensi dengan mengurangkan diameter suatu bahan berbentuk silinder. Parameter yang digunakan untuk proses melarik CNC didalam kajian ini adalah kadar suapan (mm/rev), kelajuan gelendong (rpm), kedalaman potongan (mm) dan keadaan semasa pemotongan yang akan memberi kesan kepada kekasaran permukaan pada bahan kerja sama ada dalam kualiti yang baik atau sebaliknya. Terdapat beberapa keadaan yang boleh diaplikasikan semasa proses larik dijalankan iaitu pemotongan kering, pemotongan dalam cecair penyejuk atau menggunakan penyejuk tiub vortex. Tiub vortex adalah alat yang boleh menghasilkan udara pada suhu yang berbeza iaitu suhu yang panas dan sejuk pada tiap kedua hujung tiub dimana hujung tiub dengan suhu sejuk digunakan sebagai penyejuk dalam proses larik. Di samping itu, cecair penyejuk juga digunakan didalam kajian ini untuk mengkaji perbezaan pada keputusan kajian diantara kedua-dua bahan dan alat penyejuk. Kepelbagaian parameter yang digunakan akan menentukan kualiti kekasaran permukaan dan penggunaan alat (flank wear). Kekasaran permukaan diuji menggunakan profilometer. Cara yang digunakan untuk menganalisis data adalah menggunakan kaedah DOE iaitu '2-k factorial method'. Kaedah DOE ini mengkaji empat faktor dimana setiap faktor mempunyai dua aras. Melalui kajian ini, dapat disimpulkan bahawa system penyejuk tiub vortex menunjukkan kesan positif pada kekasaran permukaan dan penggunaan alat. Kajian ini juga dapat mengenalpasti bahawa kekasaran permukaan dipengaruhi oleh kadar suapan sebagai faktor yang penting, diikuti oleh jenis penyejuk dan kelajuan gelendong. Selain itu, tiada faktor yang penting kepada bacaan dan imej penggunaan alat.

ABSTRACT

The CNC turning process is a part of material removal processing where the purpose is changing the dimension by reducing the diameter of a cylindrical workpiece. The parameters used for CNC turning in this experiment are feed rate (mm/rev), spindle speed (rpm), depth of cut (mm) and cutting condition which then resulted on the surface roughness for the workpiece either being a high-quality surface or vice versa. There are several conditions that can be used in CNC turning which are dry cutting condition, liquid cooling condition or by using a vortex cooling tube. It is a device that can release a hot and cold air at each end whereby the cold end can be used as a coolant for the turning process. Besides, the liquid coolant also used in the experiment to study the comparison. The variation of parameters used in CNC turning determine the quality of the surface roughness (R_a) and the tool wear (flank wear). The surface roughness is tested by a profilometer. The method used in analyzing the result is 2-k factorial design of experiment (DOE). This DOE explore four factors, with each factor having the minimal two levels. The investigation infers that the vortex tube cooling system shows a positive impact on the result of surface roughness and flank wear. It was identified that the surface roughness was influenced by the feed rate, followed by type of coolant and spindle speed. It was also identified that there was no significant factor influencing the flank wear.

DEDICATION

Dedicated to my mother, family and everyone who involved in this project.

Thank you for giving me moral support, money, cooperation, understanding and encouragement.

AKNOWLEDGEMENT

First, I would like to give all the praise to Allah, the most gracious, the most merciful, that I manage to complete this final year project without any difficulty. I would like to extend my sincere thanks to all individual who involved in this project for the kind support and help.

My respected supervisor, Mr. Ammar bin Abd Rahman for the guidance and constant supervision throughout the project. Besides, I would express my gratitude to my beloved co-supervisor, Mr. Mohd. Fairuz bin Dimin @ Mohd. Amin for his kind supervision, advice and guidance as well as exposing me with meaningful experiences throughout the study.

I would like to express my gratitude towards my family members for their moral support in completion of this project especially to my mother, Asnun binti Kasbon for her encouragement and my brother, Hazhan bin Husin for financial support and thanks to all my family members.

Finally, I would like to thank everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you.

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CHAPTER 1

INTRODUCTION

1.0 Background of Study

CNC machining stands for computer numerical control machining that involves the use of computers for processing the material or workpiece in manufacturing sector. In 1940-1950, The first NC machines that move the panels to follow the points fed into the system on punched tape were built. It was first discovered by John Runyon who was the person that coded the number of subroutines to produce these tapes under computer control during the development of Whirlwind. The development of CNC machine throughout the years has made it into one of the most important equipment in the industry producing high-quality product in a short period of time. Furthermore, the CNC turning machine is a machine that can contribute good surface finish for the products.

The purpose of this research is to study the CNC turning parameters by using vortex tube cooling system through the surface quality and the tool wear. In general, several controllable factors such as feed rate, spindle speed, depth of cut is operated on CNC lathe machine. Metal removal rate wear are considered as the execution measures as they influence the quality of the finished components (Harinath Gowd *et al.*, 2014).

Other than machining parameters, the surface type of the product can also affect the quality of the material used in the machining process. In this research, the material used for the workpiece is ASTM A36 mild steel while the cutting tool is cermet carbide. The relationship between the cutting tool and the workpiece must be put as one of the priorities in achieving a good surface quality. In other word, if the workpiece is made up of titanium while the cutting tool is the uncoated cermet carbide, the result of tool wear would be high. Thus, the cutting process has a poor relationship and improvement on the cutting operation is needed. Next, the wear resistance and fatigue strength are the mechanical properties which are massive effected via the surface quality of the machined components. Thus, the evaluation of the productivity of machine tools and mechanical parts is based on the quality of the surface. As a purpose to get the excellent surface quality out of the manufactured components, a right cutting circumstance identification is crucial (Sahin and Motorcu, 2005).

The response of the workpiece such as surface quality depends on some factors including the heat. The temperature increase during the turning process, thus a vortex tube was used in this research to investigate the effect of cooling on the cutting parameters. It is mechanical device that act as a refrigerating mechanism without any movement on the parts, by separating a compressed gas stream into a low and high total temperature region. The partition of the stream into moo and tall add up to temperature locale is alluded to as the temperature division impact (Karothiya and Chauhan, n.d.).

Figure 1. 1: Nexflow Vortex tube

There are some studies done on the relationship between the cutting parameter and the surface roughness of the work part. Then, there are several methods that is used to analyze the effect of machining parameters to the response of the workpiece such as Taguchi method, 2-k factorial method or response surface methodology (RSM). The evaluation in this research is done using the 2-k factorial method with the feed rate, spindle speed, depth of cut and the cutting condition as the factors in obtaining the results which are the tool wear and the surface roughness. Factorial designs would empower an experimenter to ponder the joint impact of the components on a response. A factorial plan can be either full or fractional factorial (Antony, 2014). From the design of experiment, a result of most significance factor on every response will be analyzed and an equation on each interaction between the factors and responses will be derived. Whilst factorial design techniques applied to experiments of a process, mathematical models are derived through acquired variance analysis tables. If the model is seen inadequate, it may be numerous and new experiments are organized until the most appropriate model is executed (Özbay *et al.*, 2013).

1.1 Problem Statement

Vortex tube is one of swirling tool and it also being used in various industrial applications. Vortex tube was made to become another alternative in machining operation. The result from CNC machining by using vortex tube must show an equivalent or a better response than the result of machining by standard liquid coolant, so that it could be used as one of a coolant device in the CNC manufacturing industry. The continuously usage of cutting fluid in machining operation have been improved the production and quality of parts produced by many machining sector industries. Development of coolants for object being worked on with cutting tools is to enhance the potential of cutting tool, despite that, few of coolants are unhealthy and unsafe to human and the nature habitat due to the toxicity of coolant (Kalpakjian and Schmid, 2006).

There are certain conditions for CNC turning machining that may lead to machine breakdown and production failures such as defects on the products and machine needing frequent maintenance. The cutting tool is one of the important components that need a proper attention as part of the machine care. It has a strong relationship with the feed rate; as when the feed speeds are too slow, the material remains in the cutting tool path longer than required, resulting in burns on the material. The tool needs to be examined before doing the machining process to determine whether it is still usable or not. There are several types of tool wear that can be recognized such as flank wear, edge wear, crater wear, shank wear and corner wear. Each wear resulted from the different machining process factors including cutting angle and type of tool used. An optimum value parameter would minimize the tool wear rate.

The machining process occurs on the work part will lead to an increase of the temperature on the surface of workpiece and temperature surrounding due to rotation speed and friction energy on the workpiece surface. A CNC turning machine may reach to 1 0 C on the inside. The dirt and debris blocked in the filters may push the temperature higher and later can cause damage to the machine. It is important to clear away the cutting fluid and metal shavings as they can contaminate the equipment. Other than that, there are problems in using liquid coolant in the machining such as the contamination, disposal difficulties, foaming, odor and rusting (IAMS, 2000).

In manufacturing industries, the role of surface finish on the product is important to determine the quality of the product. The secondary operation is always required in the production which in turn will increase the assembly time. Besides, the tolerance of a product would also be an issue in the manufacturing industries. Thus, a good interaction between parameters with the type of material chosen for the workpiece is required in the manufacturing industries to solve the issues.

1.2 Objective

The objective of this research is:

1. To define the correlation between surface roughness and flank wear against the feed rate, cutting speed, depth of cut and coolant type.
2. To measure the optimum parameters in fluid coolant and air vortex coolant using CNC turning.
3. To determine the significance factor (p-value) between parameters using ANOVA analysis.

1.3 Scope

This project is proposing on the using of vortex tube in CNC turning machining. It is to determine the effect of cooling on turning parameters that may contribute to higher quality products in term of surface finish and increase tool life.

The scope of this study is focusing on the turning parameter used for the process which is the feed rate (mm/min), spindle speed (rpm), depth of cut (mm) and cutting condition which is with the aid of liquid coolant and vortex tube cooling system. The vortex tube was used along the study and machining process in achieving the objective of the research. The aim of putting two cutting condition in the experiment is to study the comparison between the two types of coolant and to determine the efficiency of vortex tube in CNC machining than the liquid coolant. The material used as the workpiece in this research is a cylindrical ASTM A36 mild steel. A mild steel was used due to the suitability of the mechanical properties with the turning parameters. Other than that, it is also cheaper in price than other types of metal. The surface roughness obtained in each machining process is tested by using a roughness tester, Mitutoyo Surftest SJ-301 Profilometer. Surface roughness R_a is the average of a set of individual measurements of a surfaces peaks and valleys (Harrisonep, n.d.)

The tool wear types that will be studied in this work would be the flank wear. The image of the wear is to be analyzed from the toolmaker microscope. The tabulation of the overall data is done using the 2-k factorial method. The 2-k factorial method is one of the designs of experiment that is evaluated for a small number of variables that helps to determine the most significance factor that influence the result in the CNC machining. Next, it helps to analyze whether the vortex tube can be another alternative as a cooling system in CNC machining than other alternatives or not.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers the literature review of this project, which will describe the process of turning including the introduction on the CNC turning, turning parameter, cutting tool and the tool wear. This chapter also cover the cutting condition which divide into dry condition, liquid coolant and air coolant by vortex coolant tube. The chapter also describes the design of experiment that is applied for analyzing the process parameter. Many experimental studies on the turning parameters and cooling system have been engaged.

2.2 Turning Operation

Turning processing is a process of material removal of a rotating workpiece held by the lathe machine chuck using a contacting cutting tool. There is conventional turning machine that is controlled manually by an operator while a computer numerical control (CNC) turning machine can be run fully automated using computer coding and repeated without any operator intervention. Turning operation is one of the important machining process in manufacturing. With study on turning of diverse materials under different tooling has been going extensively. The focus of a turning process is about the cutting force, surface quality, tool wear machining time. Besides, there are several studies has been done to investigate on the effect to obtain a minimum surface roughness and tool wear.

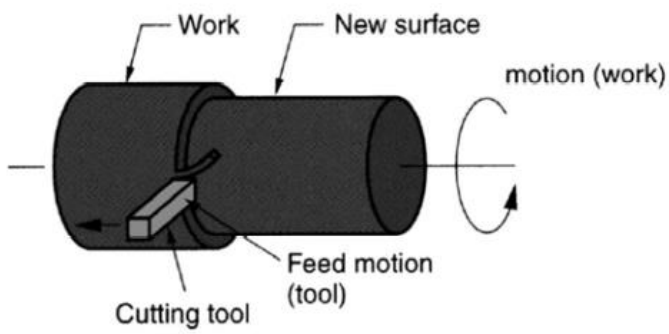

Figure 2.1: Turning operation (Butola, 2017)

2.3 CNC Turning

With the entrance of CNC innovation, the machining forms are mechanized through which tall quality machined components at tall fabric expulsion rates can be accomplished. In common, CNC machine is worked with a few controllable variables such as axle speed, bolster rate, cutting speed, profundity of cut, instrument point, and navigate speed. In this work, metal evacuation rate and tool wear are measured as the execution measures as they influence quality of the finished components. To decide the exact parameters setting of a process, the optimization of CNC turning handle is frequently accomplished by trial-and-error strategy based on the shop floor involvement (Harinath Gowd *et al.*, 2014). CNC turning is a very versatile and useful material removal operation of the modern manufacturing industries due to many advantages. Moreover, CNC turning is one of operation that provides better improvement of productivity with constant good quality parts. In CNC turning process, process parameter has a great influence on the surface roughness of the turned part. One has to optimize the process variables to obtain desired surface roughness (Rudrapati, Sahoo and Bandyopadhyay, 2016). Furthermore, for better surface quality and surface finish the effective lubrication has become an important part in turning operation (Arefi *et al.*, 2017).

Figure 2.2: Open architecture CNC turning machine employed for experiments

(Tangjitsitcharoen *et al.*, 2008)

There are numerous advantages of CNC machining process. In the term of production, CNC machines can provide a higher flexibility and a consistent quantity of production due to its process that is fully generated and automated by the NC code. The consistent quantity of production will contribute to an increase in productivity rate. The CNC machining is believed to have a reliable operation because the operation does not require any operator intervention. Thus, it reduces the lead time and non-productive time as much as if the machining operation is operated by human. Another, CNC machining also promising a high accuracy in dimension of the product. The following are the other advantages of CNC machines identified in manufacturing (Ansar *et al.*, 2016):

- Reduced scrap rate
- Reduced manpower and automatic material handling
- Shorter cycle time and just-in-time (JIT) manufacturing

2.3.1 Machining Parameter

Numerous parameters such as geometry of cutting tool, material properties, machine and cutting parameters and cutting forces may affect the performance of the metal cutting actions. Among all the parameters, cutting variables can give high impact towards the desired quality characteristics such as surface roughness (Rudrapati *et al*., 2016). Other than that, important measurement of surface quality, surface roughness (Ra) that is typically resulting from many machining parameters, along with true rake angle, cutting speed, feed rate, intensity of cut, nose radius, machining time etc. (Qehaja *et al.*, 2015).

Besides, the process parameters which are spindle speed and depth of cut are the main factor to affect the process stability (Chiappini et al., 2014). It is discovered that the feed rate is mainly affect the surface roughness followed by spindle speed and depth of cut. In machining of soft metals, application of effective lubrication may give better surface quality, which still need further investigation work (Arefi *et al.*, 2017).

2.3.1.1 Feed rate

A study on AZ31 magnesium workpiece, the feed rate change affects the surface roughness. An enhancement of the AZ31 corrosion behavior was achieved by combining the optimized machining parameters. The adoption of cryogenic cooling together with feed rates as low as 0.01 mm/rev represents an efficient strategy to improve the AZ31 corrosion behavior (Bertolini *et al.*, 2017). Additionally, an increase in feed rate causes an increase in the chip section as well as increasing considerably the cutting and feed forces (Khanna and Davim, 2015). Moreover, it is found that feed rate has the most noteworthy impact on surface harshness, taken after by nose sweep and cutting time (Qehaja *et al.*, 2015).