OPTIMIZING CNC TURNING PROCESS PARAMETER TO REDUCE SURFACE ROUGHNESS OF ALUMINIUM ALLOY 6061 IN WET AND DRY CONDITIONS

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

By

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Date : ……………………………………

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Process) (Hons). The member of the supervisory is as follows:

……………………................................

(Prof. Ir. Dr. Sivarao Subramonian)

ABSTRAK

Projek ini telah menggunakan kaedah Taguchi untuk mengoptimasikan proses mesin larik dan mengurangkan kekasaraan permukaan aloi aluminum 6061. Pengurangaan kekasaran permukaan adalah penting untuk produk automotif. Antara parameter utama yang telah dikaji dalam projek ini adalah kelajuan pemotongan, kadar hantaran mata alat, dan kedalaman pemotongan. Tahap parameter kelajuan pemotongan digunakan dalam projek ini ialah 250, 300, dan 350 m/min. Tahap parameter kadar hantaran mata alat yang digunakan dalam projek ini ialah 0.10, 0.15, dan 0.20 mm/rev. Tahap parameter kedalaman pemotongan yang digunakan dalam projek ini ialah 0.30, 0.50, 0.70 mm. Skop utama projek ini ialah untuk mencapai gred kekasaaran N5 iaitu 0.4-0.8 μm. Gred kekasaraan ini adalah dikatakan sebagai permukaan licin. Objektif projek ini adalah untuk menyiasat kesan parameter pada kekasaran permukaan, untuk membandingkan kesan pemotongan kering dan basah pada kekasaran permukaan, dan untuk megesahkan parameter optimum. Mata alat yang telah digunakan dalam projek ini adalah VCGT 160408N-AW. Alat pengukur kekasaaan yang digunakan ialah SJ-310. Analisis telah dilakukan mengunakan hasil eksperimen, kesan utama, ANOVA, dan model regresi. Projek ini telah mendapat tahu bahawa kadar hantaraan alat adalah factor yang paling ketara dan factor lain tidak begitu ketara. Selain itu, projek ini juga mendapat tahu bahawa kesan bendalir pemotongan pada kekasaran permukaan bahan kerja adalah rendah dan pemesinaan dengan bendalir memberikan kesan yang terbaik. Parameter yang optimal untuk pemotong tanpa bendalir ialah 300 m/min kelajuan pemotongan, 0.1 mm/rev kadar hantaraan mata alat, dan 0.5 mm kedalamaan pemotongan. Parameter yang optimal untuk pemotongan dengan bendalir ialah 300 m/min kelajuan pemotongan, 0.1 mm/rev kadar hantaraan mata alat, dan 0.5 mm kedalamaan pemotongan. Parameter optimal ini telah disahkan dan pemotongan tanpa bendalir mendapat peratusaan sisihan 4.2% manakala pemotongan dengan bendalir mendapat peratusan sisihan 7.5%. Projek ini juga telah mengemukakan model regrasi untuk pemotongan tanpa bendalir dan pemotongan dengan bendalir dengan peratusaan sisihan kurang daripada 10%.

ABSTRACT

In this project, the Taguchi method was used to find the optimal CNC turning process parameters to reduce surface roughness of aluminium alloy 6061. This is because low surface roughness is essential for high quality automotive parts. The main controllable turning parameters that have been investigated in this project are cutting speed, feed and depth of cut. The parameter levels of cutting speed used in this project were 250, 300, and 350 m/min. Feed levels that was used in this project were 0.10, 0.15, and 0.20 mm/rev. The parameter levels of depth of cut were 0.30, 0.50, 0.70 mm. The main scope of this project is to achieve surface roughness of N5 grade which is around 0.4-0.8 µm. This range of surface roughness value is considered as a finishing surface. The objectives of this project was to investigate effect of cutting parameters on surface roughness, to compare the effect of wet and dry machining on surface roughness and to validate the optimal cutting parameter. The cutting tool insert used in this project was an uncoated carbide insert, VCGT 160408N-AW. The work material that was used is aluminum alloy 6061. The cutting fluid employed in the project was water soluble cutting oil. The surface roughness reading was taken using portable surface roughness tester, SJ-310. Analysis was performed using experimental result, main effect analysis, ANOVA, and regression model. The findings of these analysis were that feed is the most significant factor while other factors are insignificant. Other than that, the machining condition also found to have minimal influence on surface roughness with wet machining giving the better result. The optimal parameters were found to be 300 m/min cutting speed, 0.1 mm/rev feed, and 0.5 mm depth of cut for dry machining. While, the optimal parameters were found to be 300 m/min cutting speed, 0.1 mm/rev feed, and 0.3 mm depth of cut for wet machining. Both of these optimal conditions were validated with percentage deviation of 4.2% and 7.5% for dry and wet machining respectively. This project also proposed two regression models to predict the surface roughness in dry and wet machining conditions with percentage deviation of less than 10%.

DEDICATION

For
my caring father, Manivanan
my beloved mother, Vijayaletchumi
my sweet sisters, Priyatharshini and Divyatharshini
for giving me moral support, money, cooperation, and encouragement
thank you all so much.

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Next, I would like to thank my project supervisor, Prof. Sivarao Subramonian for his encouragements and advice. He have guided me throughout my final year project. He guided and motivated me until I accomplish this project. He also have spared his precious time for me to discuss my findings and ideas. I also would like to send my gratitude to my final year project coordinator, Dr. Mohd Sukor Bin Salleh whom had also encourage me to complete the project. Other than them, I also would like to thank all technicians in CNC lab for sharing their expertise about CNC machine.

Finally, I would gladly thank my fellow classmates in UTeM whom have aided me. My classmates have shared their findings and knowledge to me so that I can refer it for my project. Some of my seniors also gave their opinion and ideas on final year project to improve my understanding. I really feel indebted to all of those whom have helped me complete my final year project.

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LIST OF ABBREVIATIONS

CNC	-	Computer numerical control
BUE	-	Build up edge
DOE	-	Design of experiment
ANOVA	-	Analysis of variance
OA	-	Orthogonal array
OHNS	-	Oil hardened non shrinkable
S/N	-	Signal-to-noise
SS	-	Sum of squares
MS	-	Mean square

LIST OF SYMBOLS

Ra	-	Arithmetic mean roughness value
µm	-	Micron
N	-	Rotational speed
v	-	Cutting speed
Do	-	Original diameter of workpiece
D_f	-	Final diameter
D	-	Depth of cut
f_r	-	Feed rate
F	-	Feed
S	-	Cutting speed
T_m	-	Machining time
L	-	Length of workpiece
MRR	-	Material removal rate
mm	-	millimeter
rpm	-	revolution per minute
min	-	Minute
rev	-	Revolution
kW	-	Kilo watt
Al	-	Aluminium
Mg	-	Magnesium
Si	-	Silicon
Fe	-	Iron
Cu	-	Copper
Mn	-	Manganese
Cr	-	Chromium
Zn	-	Zinc
Ti	-	Titanium
Wt%	-	Weight percentage
n	-	Rotational speed

v	-	Cutting speed
d	-	Depth of cut
Q	-	Quartile
L	-	Length of workpiece
R_{mr}	-	Material removal rate
L	-	Length of measurement taken
f(x)	-	Ordinate of profile curve
db	-	decibel

CHAPTER 1

INTRODUCTION

In this chapter, the details of this final year project topic have been discussed. There was brief explanation on project background. This chapter also have provided the problem statement and objective. Other than that, this part also have pointed out the scope that the project have covered and the significance of this project.

1.1 Project Background

CNC machining is one of the revolution in manufacturing industry. Currently, this advance machining technology has become widely popular in many industries. The revolution of CNC machining is mainly contributes in metal removing industry, metal fabricating industry, and electrical discharge machining industry. This project was focused on the metal removing industry.

One of the popular metal removing method in this manufacturing industry is the turning process. The turning process is very popular material removal process due to its versatility and finishing capability. Turning process is the best material removing method in terms of its capability of finishing. Kalpakjian & Schmid (2010) also stated that turning process is able to produce parts with minimum surface roughness, Ra of 0.4µm under normal application. This is the lowest surface roughness that can be produced among all the other machining processes (Kalpakjian S. &, Schmid, 2010). This allowed CNC turning machining to be used in precision industry for wide range of applications such as automotive, medical and aviation.

The surface roughness is one of the important measuring quality in precision industry apart from dimensional deviation. A precision part must possess good surface finish and low dimensional deviation. A good surface finish is important because it provides good appearance, avoid unnecessary friction in movement, and help resist corrosion. A good surface finish can be achieve with low surface roughness. A part can be produced with this quality using turning process without any need of secondary finishing processes. The materials that widely used in precision and automotive industry are stainless steel, aluminium, and bronze. Therefore, a standard aluminium alloy will be used to investigate on surface roughness which is aluminium alloy 6061. This aluminium alloy has good machinability and corrosion resistance. This material is widely used in heavy duty structures such as marine structures, pipelines, and hydraulic tubing (George F. & Ahmad K., 2000). Other than that, aluminium alloy also widely used in automotive industry to produce valve, camshaft, piston, and gears. These products require good precision for optimum service application.

The CNC turning machining parameters plays key role in producing parts with low surface roughness. Optimized parameters will be able to machine aluminium alloy 6061 to produce low surface roughness. There are many studies have been attempted to solve this issue of machining. However, coolant condition are often ignored in most of these studies. The coolant condition also effects the response variable of machining (Galanis, Manolakos, & Vaxevanidis, 2008). These factors were considered as the main challenge of producing part with low surface roughness. This project's main aim was to identify the relationship of machining parameters of turning on surface roughness in wet and dry machining condition.

1.2 Problem Statement

The CNC turning machining is a widely used machining process to produce precision products such as screws and cylindrical tools. This machine also used in automotive industry to produce precise circular parts such as camshaft, gears and piston. The precision and automotive industry must achieve specific standards of surface roughness. However, reducing surface roughness is one of the great challenge in these industries because a machining process is influenced by multiple parameter. CNC turning process parameters must be controlled and optimized to produce a good finishing products. Small deviations in these cutting parameters can affect the final surface roughness of product. Therefore, finding optimized cutting parameter to reduce surface roughness is crucial in CNC turning machining. This project will identify the effect of main cutting parameters on surface roughness and propose the optimized cutting condition.

Another problem that involve in this issue is the influence of coolant condition in machining. It is still unclear whether performing CNC turning process with or without cutting fluid is preferable for producing good surface roughness in aluminium alloy. Generally, the use of coolant in high speed machining is very important (Kalpakjian S., Schmid, 2010). This is because coolant helps to reduce machining temperature hence reducing tool wear (Debnath et al., 2016). However, it does not justify the use of coolant for finishing purpose in CNC turning. Debnath et al., (2016) claims that dry machining is good for machining steel alloy, cast iron, and steels. The coolant usage also has negative effect on health issues, cleanliness, and environmental (Anselmo Eduardo Diniz & Micaroni, 2002). In this project, the effect of coolant on surface roughness will be investigated. This will explain the role of coolant in affecting surface roughness. Apart from this, there are some difficulties in machining aluminium alloy. Despite having good machinability, aluminum alloy's ductility and gummy nature will produce continuous chip formation with built up edge (BUE) effect (Kalpakjian & Schmid, 2010; Manna & Bhattacharayya, 2003). This BUE will affect the surface roughness of the workpiece (Kuttolamadom et al., 2010).

1.3 Objectives

This project has three main objectives to be achieved.

a) To investigate the effect of cutting speed, feed, and depth of cut on surface roughness.
b) To identify and compare the effect of wet and dry machining on surface roughness of workpiece.
c) To determine and validate optimal cutting parameters that produces the lowest surface roughness in dry and wet cutting conditions.

At the end of the experiment and analysis, this project have successfully achieved these objectives.

1.4 Project Scope

This project has conducted two set of experiments to investigate the effects of cutting parameters on surface roughness. The experiments was performed under dry and wet machining conditions. This is to identify the role of coolant in machining finishing process. The machining parameters that have been tested are cutting speed, feed rate, and depth of cut. Even though there are some uncontrollable factors influencing the surface roughness, only these controllable parameters are tested in this project. The main uncontrollable factor is the tool vibration. This experiment does not study on this uncontrollable factor because it is unpredictable and requires special tools such as accelerometer for measuring. This project also aims to achieve N5 roughness grade which is 0.4-0.8 μm. This is because roughness grade below N7 was considered to be finish surface.

The specimen or workpiece that has been used was aluminium alloy 6061-T6511 rod with dimensions of 150mm length and 50mm diameter. The CNC lathe machine that have been used to perform turning process is Hass SL-20. The cutting tool insert that have been utilized to cut workpiece is a carbide insert, VCGT160408. The surface roughness of machined parts was measured using portable surface roughness tester, Mitutoyo SJ-301. The arithmetic mean roughness, Ra of workpiece was measured and recorded. Then this data was analysed using Taguchi main effect, ANOVA, and regression model. Then, mathematical equation was proposed using fit regression model. Finally, that optimized parameter and the model have been validated in confirmation test.

1.5 Project Significance

This project was mainly focused on reducing a surface roughness in CNC turning process machining. This have been achieved by manipulating the CNC cutting parameters such as cutting speed, feed, and depth of cut. This project has clarified the relationship of cutting parameter on surface roughness. Therefore, industries will be able to identify the main parameter that is influencing the surface roughness of parts. This will greatly benefit the automotive and precision industries to produce parts with low surface roughness. Other than that, this project also will help these industries to avoid some unnecessary process such as conventional grinding to reduce surface roughness. Other than that, this project also explained about the role of coolant in reducing surface roughness. This will help the industry to understand the effect of coolant. If the coolant does not have any significant effect on the surface roughness, it is wise for the industry to avoid the usage of coolant in machining. This is because avoiding coolant can help the industry to reduce machining cost and to avoid any unnecessary issues such as cleaning and contamination (Deepak et al., 2014). At the end of this project these issues have been solved.

CHAPTER 2

LITERATURE REVIEW

In this chapter, all the previous studies involved to this project was discussed. Those previous studies are composed of journal, books and thesis. This literatures has helped to further understand the project deeply. All the research papers have been compared and analysed effectively.

2.1 Turning Process

Turning process is a material removal method that machines a horizontally revolving cylindrical workpiece. The cylindrical workpiece will be gripped in spinning spindle, then the cutting tool will be feed into the workpiece to remove its material as explained by Ronald A., & Denis R. (2006). The Figure 2.1 clearly illustrates the turning process with workpiece rotation and tool feed. Basically, turning process can be classified into two main cutting processes as stated by George F. & Ahmad K. (2000). Those are cutting in the center of rotating workpiece such as drilling, boring, and reaming. Another type is the cutting done on the horizontal surface of revolving workpiece such as straight turning, threading, and contour turning.

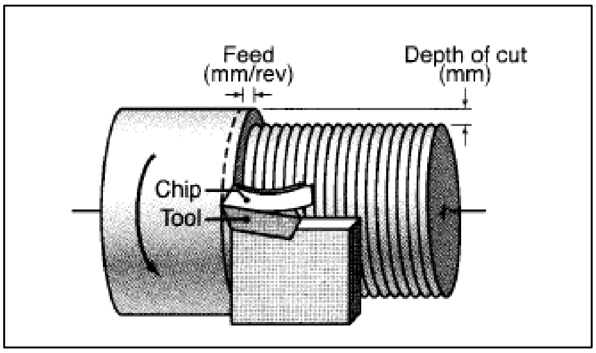

Figure 2.1: Schematic representation of turning process (Serope Kalpakjian & Steven R., 2010).

According to Mikell P. Groover (2007), there are few important cutting conditions involve in turning process. Those conditions are rotational speed (N), feed rate (f_r), final diameter (D_f), machining time (T_m), and material removal rate (R_{MR}). First, the rotational speed is described as the cutting speed of the turning process on a surface of round workpiece as given in the equation 2.1. According to Mikell P. Groover (2007) feed rate of turning process is the total linear feed cut per minute as given in equation 2.2. Next, final diameter is the desired diameter that the process will produce. This can be find using equation 2.3 which is the difference of original diameter (D_0) and two times of the depth of cut (d). Then, machining time is described as time needed to finish a cutting process. This can be calculated using equation 2.4. Finally, there is the material removal rate which is the total volume of materials removed per minute as shown in equation 2.5. These are the important cutting conditions that must be known before machining turning process.

$$rotational\ speed, N = \frac{v}{\pi Do} \qquad \text{Equation 2.1}$$

$$feed\ rate, fr = NF \qquad \text{Equation 2.2}$$

$$final\ diameter, Df = Do - 2d \qquad \text{Equation 2.3}$$

$$machining\ time, Tm = \frac{L}{fr} \qquad \text{Equation 2.4}$$

$$material\ removal\ rate, MRR = vfd \qquad \text{Equation 2.5}$$

2.1.1 Surface finishing

Surface finish is one of important quality in precision industry after dimensional tolerance. Turning is considered one of good surface finishing in machining process (Kalpakjian S., Schmid, 2010). A turning process is able to produce part with good surface finishing without any secondary finishing processes. This good finishing quality is important for parts because it provide good visual traits, reduce frictions, and also provide corrosion resistance. Turning process is able to produce arithmetic mean surface roughness as low as 0.40μm in their average application. However, the parameters of CNC turning must be optimum for turning process to produce good surface finished products.

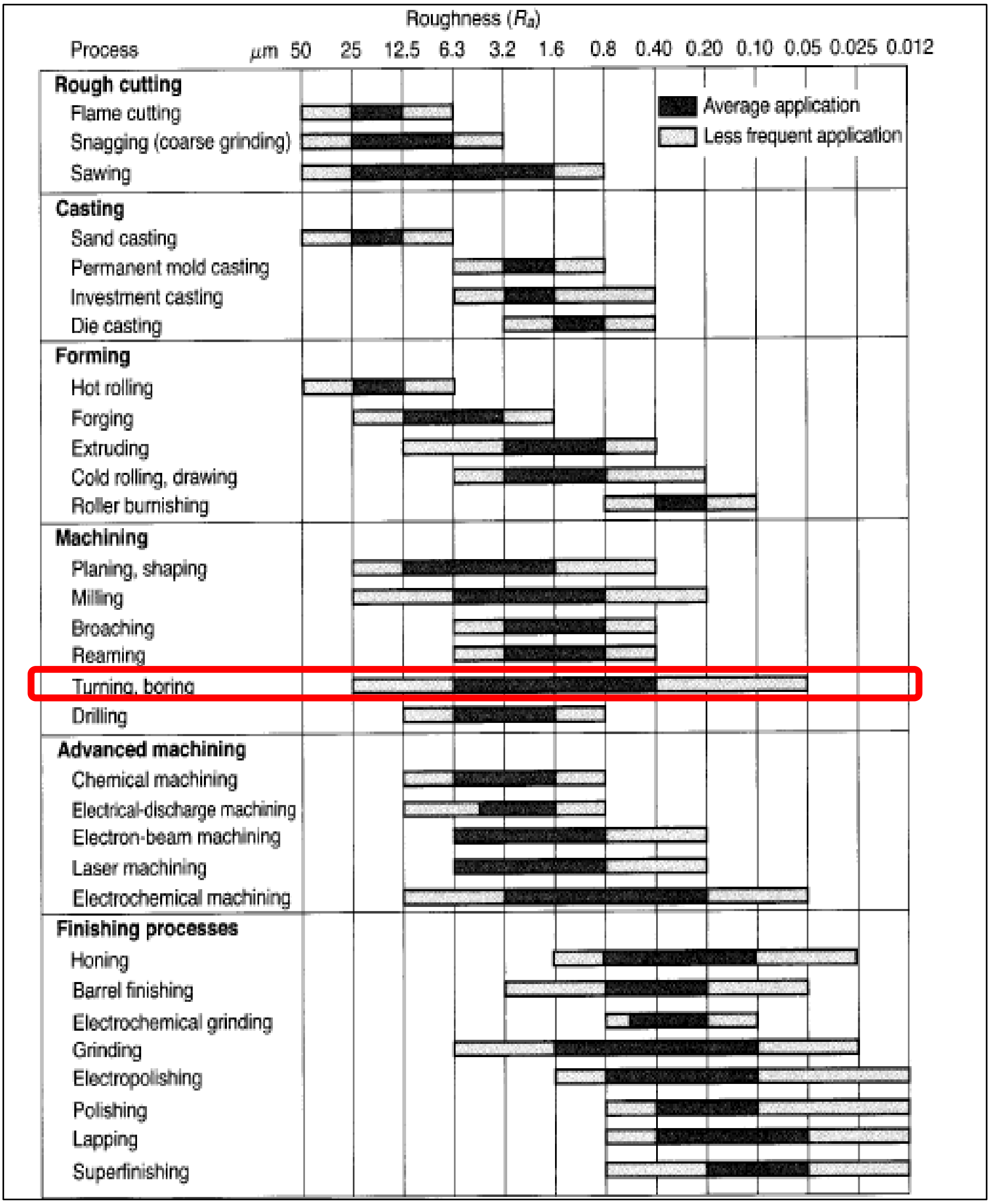

Figure 2.2: Surface roughness of varies process (Kalpakjian & S., Schmid, 2010).

2.2 Parameters of CNC turning

A CNC turning operation has many parameters to be considered before start machining. Harish Kumar, et al, (2013) have explained about all major parameters that involves in CNC