UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF MACHINING PARAMETERS IN TURNING PROCESS OF ALUMINUM ALLOY 6063

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotic and Automation) with Honours.

by

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotic and Automation) with Honours. The member of the supervisory committee is as follow:

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OPTIMIZATION OF MACHINING PARAMETERS IN TURNING PROCESS OF ALUMINUM ALLOY 6063

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ABSTRACT

This report presents an optimization of machining parameters in turning process of Aluminum alloy 6063 T6. OKUMA LCS-15 horizontal turning machines have been used to run the experiments on Aluminum alloy 6063 T6. Aluminum is widely used in automotive industry, aerospace applications, architectural applications and others. The main objective of the research was to determine the effect of different parameters setting such as depth of cut, feed rate and cutting speed on surface roughness and hardness. In this research, the RSM (response surface methodology) method with Central Composite Design (CCD) was used to design the experiment and 20 trials were conducted. The machined surface was checked by using portable surface roughness tester and hardness was measured by using Digital Micohardness tester. The quadratic model was selected in the analysis of variance (ANOVA) and the model graph revealed the interaction between the three controllable parameters. The analysis revealed that cutting speed was the significant effect to the surface roughness followed by the feed rate while depth of cut was less effect. The best surface finish can be obtained with the combination of lowest cutting speed and feed rate. Besides, the numerical optimization method was employed in the optimization and the best predicting setting was depth of cut 0.69 mm, feed rate 0.09 mm/rev and cutting speed 153.14 m/min. The average deviation percentage value was 54.84%. In the experiment, the hardness was influenced by the cutting speed and feed rate. The highest of cutting speed and feed rate will cause hardness decreasing.

ABSTRAK

Laporan ini menerangkan pengoptimuman parameter dalam proses pemesinan larik pada Aluminium alloy 6063 T6. Okuma SKB-15 mesin larik melintang digunakan untuk menjalankan eksperimen pada bahan kerja Aluminium 6063 T6. Aluminium banyak digunakan dalam industri automotif, angkasa aplikasi, arsitektur aplikasi dan lain-lain. Objektif utama dari penelitian ini adalah untuk menentukan kesan daripada tatacara parameter yang berbeza seperti kedalaman pemotongan, kadar suapan dan kelajuan dalam pemotongan ke atas kekasaran permukaan dan kekerasan. Dalam kajian ini, kaedah RSM (response surface methodology) bersama dengan Central Composite Design (CCD) digunakan untuk merancang percubaan bagi eksperimen ini dan 20 uji kaji telah dijalankan dengan merujuk kepada jadual matriks. Permukaan yang telah dimesin diperiksa dengan menggunakan alat uji kekasaran permukaan mudah alih dan kekerasan diukur dengan menggunakan Digital Micohardness tester. Model kuadratik dipilih dalam analisis varians (ANOVA) dan model grafik mendedahkan interaksi antara tiga parameter yang dikendalikan. Analisis menunjukkan bahawa kelajuan pemotongan adalah pembolehubah yang signifikan terhadap kekasaran permukaan diikuti oleh kadar suapan sementara kedalaman pemotongan adalah kurang signifikan. Permukaan terbaik boleh didapati dengan kombinasi kelajuan pemotongan dan kadar suapan dengan nilai yang terendah. Selain itu, kaedah pengoptimuman berangka telah digunakan dalam optimasi dan tatacara yang terbaik untuk meramalkan adalah kedalaman pemotongan 0.69 mm, kadar suapan 0.09 mm/rev dan kelajuan pemotongan 153.14 m / min. Nilai rata-rata deviasi peratusan adalah 54.84%. Dalam eksperimen ini, kekerasan telah dipengaruhi oleh kelajuan pemotongan dan kelajuan secara maklumnya. Peningkatan kelajuan pemotongan dan kadar suapan secara maklum akan menyebabkan penurunan kekerasan.

DEDICATION

To my lovely family and fellow friends that accompanying me along the difficult pathway in my university life, thanks for your help and support.

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LIST OF ABBREVIATIONS

AA	-	Arithmetic Average
ANOVA	-	Analysis of Variance
BUE	-	Build-up-edge
CCD	-	Central Composite Design
CLA	-	Center Line Average
CNC	-	Computerized Numerical Control
CVD	-	Chemical-vapor Deposition
DF	-	Degree of Freedom
DOC	-	Depth of Cut
DOE	-	Design of Experiment
HRC	-	Rockwell Hardness Number
HSS	-	High Speed Steel
HV	-	Vickers Hardness
Prob	-	Probability
PVD	-	Physical-vapor Deposition
RPM	-	Revolution per Minute
Ra	-	Roughness Average
RSM	-	Response Surface Methodology
SCEA	-	Side Cutting Edge Angle
SEM	-	Scanning Electron Microscope
SiC	-	Silicon Carbide
SS	-	Sum of Squares
TiC	-	Titanium Carbide
TiCN	-	Titanium Carbonitride
TiN	-	Titanium Nitride
UTeM	-	University Teknikal Malaysia Melaka
UTHM	-	University Tun Hussein Onn Malaysia

CHAPTER 1

INTRODUCTION

This chapter describes the introduction of the project and briefly explained the problem statements and objective in the research. This chapter also included the scope and the importance of the study for the project.

1.1 Introduction

In this challenge world, industries around the world constantly strive for lower cost solutions with reduced lead time and better surface quality in order to maintain their competitiveness. Automated and flexible manufacturing systems are employed for that purpose along with computerized numerical control (CNC) machines that are capable of achieving high accuracy and very low processing time (Nalbant, 2006). In the CNC machining, determining optimal cutting conditions or parameters under the given machining situation is difficult in practice. Conventional way for selecting these conditions such as cutting speed and feed rate has been based upon data from machining handbooks and/or on the experience and knowledge on the part of programmer. As a result, the metal removal rate is low because of the use of such conservative machining parameters (Kyung and Soung, 1997).

Turning is the first most common method for cutting and especially for the finishing machined parts. In a turning operation, it is important task to select cutting parameters for achieving high cutting performance. Cutting parameters are reflected on surface roughness, surface texture and dimensional deviations of the product (Nalbant, 2006).

Surface finish obtained in manufacturing processes mainly depends on the combination of two aspects: the ideal surface finish provided by marks that manufacturing process produces on the surface and the actual surface finish which is generated taking into account irregularities and deficiencies that may appear in the process, changing manufacturing initial conditions (Arbizu and Perez, 2002).

The surface of every part includes some type of texture created by any combination of the following factors; the microstructure of the material, the action of the cutting tool, cutting too instability, errors in tool guide ways and deformations caused by stress patterns in the component.

The surface texture of an engineering component was very important. It was affected by the machining processes by changes in the conditions of either the component or machine (Abouelatta and Madl, 2000). A machined surface carries a lot of valuable information about the process including tool wear, built-up edge, vibrations, damaged machine elements etc. Under stable machining conditions, the surface texture changes remarkably due to the changes in the cutting tool shape caused by wear. Since the cutting tool operates directly on the workpiece during a machining operation, it affects the texture of the workpiece surface which in turn provides reliable and detectable information to categorize the condition of the tool. Consequently, a machined surface is a replica of the cutting edge which carries valuable information related to the tool condition (i.e., sharpness or bluntness) (Kasim *et. al.* 2006).

The purpose of this project was to investigate the surface roughness and hardness on engineering component by turning process. To achieve the result of surface roughness and hardness, the material used for the investigation was aluminum alloy 6063 T6. Thus, the surface roughness and the hardness was measured and observed in the experiment. The RSM method was used to design the variables of cutting parameter in the experiment in order to obtained data of various specimens. Optimization was involved in the research to provide a better surface roughness prediction for turning aluminum alloy.

1.2 Problem statement

In machining operations, the quality of the surface finish was playing an important role for many turned workpieces. However, human operators or programmer normally inspecting the surface according to their experiences or refer from machining handbooks. With regarded to the quality characteristics of turning parts, some of the problems included surface roughness, burr, and tool wear, etc. The machining parameters such as cutting speed, feed rate, depth of cut, features of tools, work piece material and coolant conditions were highly affect the performance characteristics. It was necessary to select the most appropriated machining settings in order to improved cutting efficiency, process at low cost, and produced high-quality products.

a) What are the relationships between the controllable factors (in the study: spindle speed, feed rate, and depth of cut) and the response factor (surface roughness and hardness)?
b) What are the most controllable factors that produced a better surface finish?

1.3 Objective

- To study the effect of different parameters to the surface roughness and hardness of aluminum alloy 6063 using RSM (response surface methodology) method.
- To optimize the parameters for surface roughness.

1.4 Scope

The study was aim on the spindle speed, feed rate, and depth of cut on the surface roughness and hardness of workpiece. The aluminum alloy 6063 T6 was used as the workpiece material and the insert that used in the cutting process was TNMG 160408 ML TT3500 CVD coated carbide inserts. In addition, the machining process was under the wet environment. The surface roughness was tested by using portable surface roughness tester, SJ301. Besides, the hardness of the materials was tested by using Affri Digital Microhardness Tester. The parameters that not cover in the research were tool wear, nose radius, edge preparation, insert angle, cutting forces and others.

1.5 Importance of study

The importance of this study was to investigate the surface roughness and hardness produce by different controllable parameter such as cutting speed, feed rate and depth of cut by turning aluminium alloy 6063. By using the RSM method, it was easy to established variables parameters in design the experiment. Besides, the technique of the optimization was implemented for obtained better surface finish values.

1.6 Result expected

At the end of this study, it was expected that the effect of different parameters to the machined surface and hardness can be obtained. The optimum parameters were obtained simultaneously.

CHAPTER 2

LITERATURE REVIEW

This chapter describes the turning process and the parameters influenced to the surface roughness and hardness by referred from the previous journal. Besides, the method that used for design the experiment was also explained in this chapter.

2.1 Turning Process

In modern industry the goal is to manufacture low cost, high quality products in short time. Automated and flexible manufacturing systems were employed for that purpose along with computerized numerical control (CNC) machines that are capable of achieving high accuracy and very low processing time. Turning was the most common method for cutting and especially for the finishing machined parts. Furthermore, in order to produce any product with desired quality by machining, cutting parameters should be selected properly (Chorng *et. al.,* 2008).

Turning was a widely used machining process in which a single-point cutting tool removes material from the surface of a rotating cylindrical workpiece. Three cutting parameters, i.e., cutting speed, feed rate, and depth of cut, must be determined in a turning operation. Common methods of evaluating machining performance in a turning operation are based on the following performance characteristics: tool life, cutting force, and surface roughness. Basically, tool life, cutting force, and surface roughness are strongly correlated with cutting parameters such as cutting speed, feed rate, and depth of cut (Nian *et. al.,* 1998).

Turning constitutes the majority of lathe work. Thus, it was the process of machining straight, conical surfaces, external cylindrical, curved and grooved workpieces. The cutting tool was attached to the tool post, which is driven by the lead screw, and removes material by travelling along the bed (Kalpakjian, 2006).

2.2 Parameters

In turning process, there have lot of parameters that will influence the process such as tool geometry, cutting speed, depth of cut, etc. The consideration needed to make to determine the effect of cutting parameters on the work piece. Lalwani *et al.* (2007) has made an experimental investigation on the effect of cutting parameters such as cutting speed, feed rate and depth of cut on the feed force, thrust force, cutting force and surface roughness in finish hard turning of MDN250 (50 HRC) steel using coated ceramic tool. They found that the cutting speed has no significant effect on cutting forces and surface roughness. But before the researcher has stated that the cutting speed has greater influence on roughness followed by the feed and the depth of cut has no significant influence on the roughness according by Davim (2001). He also mentioned that the interaction cutting velocity/feed is the most important of the other analyzed parameters.

Besides that, Nalbant *et al.* (2006) also found that the insert radius and feed rate are the main parameters among of three controllable factors (insert radius, feed rate and depth of cut) that influence the turning process. Noordin *et al.* (2003) has applied the RSM in investigation into the effect of feed rate, side cutting edge angle (SCEA) and cutting speed on the surface roughness and tangential force. He revealed that feed is the most significant factor influencing the response followed by the SCEA. Moreover, a test were conducted to find the effect of tool parameters such as insert shape, cutting edge preparation, type and nose radius by Arunachalam *et al.* (2004). Another authors, Dahlman *et al.* (2003) show that tool geometry as well as cutting parameters affects residual stresses in the experiments. The authors also show that a negative rake angle gives higher compressive stresses and feed was significantly higher compressive stresses. But the cutting depth does not affect the residual stresses as well.

According to the past researches, there have lot of parameters such as cutting feed, feed rate, depth of cut, nose radius, rake angle, insert material, etc. But cutting speed, feed rate and depth of cut were considered as the most significant cutting parameters for turning process.

2.2.1 Cutting Speed

In general, speed (V) was the primary cutting motion, which relates the velocity of the rotating workpiece with respect to the stationary cutting tool. The cutting speed refers to the edge speed of the rotating workpiece. It is generally given in unit of surface feet per minute (sfpm) or inches per minute (in. /min), or meters per minute (m/min). For a given material there will be an optimum cutting speed for a certain set of machining conditions, and from this speed the spindle speed (RPM) can be calculated (Kalpakjian, 2006). Factors affecting the calculation of cutting speed are:

i. The material being machined (steel, brass, tool steel, plastic, wood)
ii. The material the cutter is made from (Carbon steel, High speed steel(HSS), carbide, ceramics)
iii. The economical life of the cutter (the cost to regrind or purchase new, compared to the quantity of parts produced).

$$V = \pi D N_s \qquad (1)$$

Where,
V = speed (m/min, in/min, m/rev)
N_s = Spindle speed (RPM)
D = diameter of the material