UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECTS OF CUTTING PARAMETERS ON SURFACE ROUGHNESS OF ALUMINIUM AL6061 WHEN MACHINING USING 3-AXIS CNC MILLING MACHINE

This report is submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

by

NURHAYATI BT AMIR NURDIN

B071210359

900426-08-6264

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Manufacturing) (Hons.). The member of the supervisory is as follow:

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(MR. SALLEH BIN ABOO HASSAN)

ABSTRACT

Surface quality is an important in higher manufacturing industry. The surface quality can evaluate the productivity of cutting tool, machine condition and also machining parameter. This study presents the analysis on the effects of cutting parameters on surface roughness of Aluminium Al 6061 when machining using 3-axis CNC milling machine. The objective of this study was to analyzed the effects of spindle speed, feed rate and depth of cut on surface roughness when machining Aluminium Al 6061. Moreover, to determine the optimum process parameter setting and validate the result when machining Aluminium Al 6061 by using Taguchi method analysis are also the objective of f this study also. As the Taguchi method analysis is one of the best methods to design and analysis the experiment, this method was used in this experiment. There are three levels of parameter were conducted by using 3–axis CNC milling machine and 9 pieces of Ø10 mm end mill cutting tools were used to conducted this experiment. The surface roughness of the specimen part was measured by using surface roughness tester and was analyzed by using Taguchi method analysis design of experiment in Minitab 17 software. The Taguchi method design of experiment that has been suggested was effective and powerful as the optimum parameter results obtained was give the best surface roughness value for Aluminium Al 6061 by using this method. Another achievement is this Taguchi method is more usefully in designing of experiment as it has a step by step to achieve the experiment.

ABSTRAK

Kualiti permukaan adalah penting dalam industri pembuatan yang lebih tinggi. Kualiti permukaan boleh menilai produktiviti mata alat pemotongan, keadaan mesin dan juga parameter pemesinan. Kajian ini membentangkan analisis mengenai kesan memotong parameter pada kekasaran permukaan Aluminium Al 6061 apabila pemesinan menggunakan 3 paksi mesin CNC. Objektif kajian ini adalah untuk menganalisis kesan kelajuan gelendong, kadar suapan dan kedalaman pemotongan pada kekasaran permukaan apabila proses pemesinan menggunakan material Aluminium Al 6061. Lebih-lebih lagi, untuk menentukan tetapan parameter proses yang optimum dan mengesahkan hasilnya apabila proses pemesinan menggunakan material Aluminium Al 6061 dengan menggunakan kaedah Taguchi juga objektif kajian ini. Taguchi adalah salah satu kaedah yang terbaik untuk mereka bentuk dan analisis eksperimen dan kaedah ini telah digunakan dalam eksperimen ini. Terdapat tiga tahap parameter telah dijalankan dengan menggunakan 3-paksi mesin CNC dan 9 mata alat Ø10 mm end mill telah digunakan untuk menjalankan eksperimen ini. Kekasaran permukaan bahagian spesimen telah diukur dengan menggunakan penguji kekasaran permukaan dan dianalisis dengan menggunakan Taguchi reka bentuk analisis kaedah eksperimen dalam Minita 17 perisian. Reka bentuk eksperimen kaedah Taguchi yang telah dicadangkan adalah berkesan dan berkuasa kerana keputusan parameter optimum diperolehi ialah memberi nilai kekasaran permukaan terbaik Aluminium Al 6061 dengan menggunakan kaedah ini. Pencapaian lain adalah kaedah Taguchi ini adalah lebih berguna dalam mereka bentuk eksperimen kerana ia mempunyai langkah demi langkah untuk mencapai eksperimen.

DEDICATIONS

To my beloved father, Amir Nurdin bin Mohd Isa and mother, Maznah binti Mokhtar and all my siblings.

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LIST OF SYMBOLS AND ABBREVIATIONS

Al	=	Aluminium
CNC	=	Computer Numerical Control
DOE	=	Design of Experiment
HSS	=	High Speed Steel
S/N	=	Signal Noise
TIG	=	Tungsten Inert Gas

CHAPTER 1
INTRODUCTION

1.0 Introduction

In this chapter one, project background, problem statement, project objective and project scope of this experiment was stated.

1.1 Background

In an extensive range of manufacturing industry, Aluminium material are widely used in various industries such as automotive, aerospace, and the industry in which weight is the most important factor. It is prominent to know the properties behaviour of the material before it can be used. In this research, cutting parameter is the significant things to correlates it with the effect of the surface roughness on the part. It is includes spindle speed, feed rate and depth of cut of machining Aluminium Al6061 part with the different value of cutting parameter on 3-axis CNC milling machine.

Surface roughness plays an important role in surface finish of product after machining process. Surface finish is a key machining process to determining good quality of product due to the increasing demand of higher precision components. It affects not only the dimensional accuracy of machined parts, the properties of parts especially the fatigue strength and the corrosion resistance, helps in higher reducing the cost of machining. The Taguchi method is statistical tool that efficient to investigate the influence of cutting parameters such as spindle speed, feed and depth of cut. It also can optimize the performance, quality and cost on the surface roughness under study.

1.2 Problem Statement

There have been many great research developments in modeling surface roughness. Quality of machining processes can be judged by surface roughness of the part. Higher the surface finish the higher will be the quality. An optimization of only proper selection of cutting parameters can produce a better surface finish. Producing the good surface roughness is not only affects the functional features of products, it also affects the cost of manufacturing. Taguchi method was applied in this research to achieve the optimum parameter that will use for machining Aluminium Al6061 on 3-axis milling machine. Minitab software was used in this research to analyze the data.

1.3 Project Objective

The objectives of this project to achieve are:

i) To determine optimum process parameter setting when machining Aluminium Al 6061 by using Taguchi Method Design of Experiment.

ii) To analyze the effects of spindle speed, feed rate and depth of cut on surface roughness when machining Aluminium Al 6061.

1.4 Project Scope

This research was focused on the surface roughness of the Aluminium Al-6061 material using end mill Ø10mm cutting tool on 3-Axis CNC Milling Machine. There are three types of cutting parameters were used. There are spindle speed, feed rate and depth of cut. CATIA software was used to design and program the part before start the machining processes. The machining process was conducted by using CNC Milling machine. The surface roughness tester was used to test and measure the surface of the part after machining based on surface roughness parameter Ra. This research also applied design of experiment Taguchi method to find the optimum cutting condition by using Minitab 17 software. Lastly, all the data and results obtained were discussed accordingly.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter provides a literature review by the previous researched taken from journal articles, books and other sources. It is include the information about aluminium Al 6061, end mill cutting tools and 3-axis CNC milling machine, cutting parameter, surface roughness and design of the experiment.

2.1 Aluminium Al 6061

It has a special and unique combination of properties that make it suitable for many different applications in various alloy forms. The main properties which make aluminium is a unique material are its low density, strength, recyclability, corrosion resistance, durability, ductility, formability and conductivity. Due to this unique combination of properties, the variety of applications of aluminium continues to increase.

According to Mathew, Sina and Mears (2010) on the research of effect of Machining Feed on Surface Roughness in Cutting 6061 Aluminum, Aluminum is the second most plentiful metallic element and structural metal in the earth's crust. It is mostly extracted by the chemical refinement of bauxite using the Bayer process to form aluminum oxide (alumina) from which (99.9% pure) aluminum extracted by the Hall-Heroult method. It is commercially available as wrought or cast in the form of ingots, bars, sheets, etc. It has good electrical and thermal conductivities as well as good ductility and malleability. Also, it can be surface finished within a wide range of values. Some of the limitations of aluminum are lower strength at elevated temperatures, limited formability and relatively higher cost compared to steel.

2.1.1 Common Aluminum Alloys and Applications

Aluminium Al6061 is material hardening aluminium alloy which containing combination of magnesium and silicon as its major alloying elements. Have a good weldability and good mechanical properties as on one the chracteristics of this type aluminium material. Aluminium Al6061 material is one of the most common alloys of aluminium for general purpose use. Table 2.1 shows the typical properties and applications of Aluminium alloy.

Table 2.1 Typical aluminium alloy properties and applications

	type	characteristics	Example of usage
Non-heat-treatable	1000 (pure aluminum)	Aluminum content is 99.00% or greater. Excellent processability, anti-corrosion, weldability, and thermal conductivity, but not suitable for construction material due to its low strength.	Household articles, daily necessities, electric appliances, and radiators
	3000 (Al-Mn)	Strength is slightly improved with addition of Mn (manganese) without deteriorating aluminum processability and anti-corrosion characteristic.	Containers (cans) and construction materials (roof material)
	4000 (Al-Si)	CTE(coefficient of thermal expansion) is restrained and wear resistance is improved with addition of Si (silicone). Alumite film shows gray color from dispersion of Si particles.	Forged piston materials, and exterior panels for building construction
	5000 (Al-Mag)	Various alloy materials are available depending of composition of Mg (magnesium). Best strength performance among non-heat-treatable alloys.	Automobile interiors and welded structural materials for vessels and automobiles
Heat-treatable	2000 (Al-Cu-Mg)	Duralmin is its popular name and its strength is equivalent to steel material. But with relatively large contents of Cu, anti-corrosion characteristics and weldability are inferior to the other alloys.	Construction material for aircraft, High-intensity forged material, and machinery parts as free-cutting alloy
	6000 (Al-Mg-Si)	The most popular construction material due to excellent strength and anti-corrosion properties. 6063 has excellent workability in extruding and is used as sash (window frame) material.	Building material for window frame
	7000 (Al-Zn-Mg)	The best strength performance among aluminum alloys.	Welded structural material for automobile and sporting goods.

Table 2.2 Aluminium Alloy and Temper

Aluminium Alloy and Temper	**Typical Properties and Applications**
1100-O 1100-H14	Commercially pure aluminum resistant to chemical attack & weathering, low cost, ductile for deep drawing & easy to weld, used in chemical equipment, fan blades, sheet metal work.
2014-O 2014-T4, T451 2014-T6, T651	Truck Frames, aircraft structures, automotive parts, cylinders &pistons, machine parts, structural applications
2017-T4, T451	Fasteners, fittings
2024-O 2024-T3, T4 2024 -T351 Alclad	High strength structural applications, excellent machinability in T-temper, fair workability &corrosion resistance, alclad combines high strength and corrosion resistance, used in truck wheels, aircraft structures, automotive parts, fasteners, recreation equipment, screws & rivets.
3003-O 3003-H12 3003-H14 3003-H16	Most popular general-purpose alloy, stronger than 1100 with same good formability & weldability, used in cooking utensils, chemical equipment, pressure vessels, sheet metal work, builder's hardware, storage tanks, trucks & trailers, architectural.
3004-O 3004-H38	Sheet metal work, storage tanks, agricultural applications, building products, containers, electrical applications, furniture, trucks &trailers
3105-O 3150-H14 3150-H18	Siding, sheet metal work, automotive parts, building products, electronics, furniture, trucks & trailers

3150-H25	
3105-O 3150-H14 3150-H18 3150-H25	Siding, sheet metal work, automotive parts, building products, electronics, furniture, trucks & trailers
5005-H34	Appliances, utensils, architectural, electrical conductors, general sheet metal, hardware, marine applications
5052-O 5052-H112 5052-H32 5052-H34	Stronger than 3003, readily formable, good weldability & resistance to corrosion, used in sheet metal work, hydraulic tube, appliances, pressure vessels, hardware signs, marine applications, trucks
6061-O 6061-T4 6061-T6, T651	Good formability, weldability, corrosion resistance, & strength in the T-tempers, good general-purpose alloy used for a broad range of structural applications & welded assemblies, pipeline, marine applications, furniture, agricultural applications, aircraft's, architectural, building products, chemical equipment, electrical and electronic parts, fasteners, general sheet metal, recreation equipment, storage tanks
6063-T5 6063-T6	Pipe railing, furniture, architectural extrusions, marine applications, truck & trailer, recreation equipment, building products, electrical and electronic parts
7050-T7651	High strength alloy in aircraft & structures, recreation equipment

2.1.2 Surface Treatment for Aluminium

Aluminum alloys are divided into two major categories which is wrought and casting alloys. A differentiation for each category is based on mechanism of property development. Many alloys respond to thermal treatment based on phase solubility. These treatments include solution heat treatment, quenching and precipitation, or age hardening. To improve surface properties of final products such as wear resistance, corrosion resistance, reflectivity etc., different types of surface treatment were used. All of the treatments are divided into several groups. Table 2.3 indicate types of surface treatment of aluminium alloys

The most common types of surface treatment for aluminium alloys are:

i. Degreasing
ii. Mechanical surface treatment
iii. Chemical surface treatment
iv. Chemical conversion
v. Chemical brightening
vi. Anodising (anodic oxide)
vii. Powder coating
viii. Wet coating

Table 2.3 Types of surface treatmet

Type	Technique	Characteristics
Extruded	Fine lines on extruded surface	Decoration Guidelines to future positioning. Fine lines cover small imperfections.
Mechanical	Grinding / brushing	Fine lines in the direction of grinding. Gives a silk or matt appearance. Produces a flat even surface.
	Polish and buffing	The grinding lines partly disappear with polishing. Reduces “stress risers”. Removes die lines and tool marks and surface blemishes.
	Vibration polishing	Yields a matt to shiny surface suited to small batches and mass produced parts.
	High finish polishing	Mirror finish, usually followed by bright anodising.
	Shot / grit blasting	For cast aluminium components to remove cast skin and improve appearance.
Chemical	Milling	Removes surface to desired depth. Can be used for signwriting.
	Etching	Pretreatment to various finishing processes. Leaves a matt or silky appearance. Different etchants leave slightly different textures that may show up in anodising sheen
	Brightening (prior to anodising)	Removes surface texture and gives a mirror finish. Film usually < 15 microns
	Chromating /	Pretreatment prior to powder or

	phosphating	other coating systems.
	Electrochemically plating with copper, tin, nickel or silver	Improves corrosion resistance / gives good soldering surface / conductivity and reflectivity.
Electrochemical	Decorative anodizing	Gives a hard, natural or coloured oxide layer up to 25 microns. Mainly for decoration - resists pitting corrosion but also adds wear resistance and electrical insulation.
	Hard anodizing	Gives a grey to brown coloured hard oxide layer of 75 - 125 microns. Mainly used for engineering purposes to resist abrasion / wear.
	Electrolytic polishing	Gives a smooth surface with high reflectivity.
Organic surface Coating	Powder coating	Gives various degrees of protective and decorative finishes that can withstand heavy chemical attack (provided surface coating is unbroken).
	Screen printing	Printing of text, décor patterns, etc.
	Coating with protective foils	For decoration, protection or other properties.
	Wet coating	Mainly used in capital intensive operations for coil coating, effective and efficient. Mainly for building industry.