INVESTIGATION ON THE SURFACE ROUGHNESS OF THE NIMONIC C-263 ALLOY DURING TURNING UNDER DIFFERENT MACHINING CONDITIONS

TUAN NORLIZA HANIM BINTI TUAN HUSSIN

B051910034

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

INVESTIGATION ON THE SURFACE ROUGHNESS OF THE NIMONIC C-263 ALLOY DURING TURNING UNDER DIFFERENT MACHINING CONDITIONS

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the bachelor's degree of Manufacturing Engineering (Hons.)

By

TUAN NORLIZA HANIM BINTI TUAN HUSSIN

B051910034

980624-03-6594

FACULTY OF MANUFACTURING ENGINEERING

2022

Appendix B1

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **INVESTIGATION ON THE SURFACE ROUGHNESS OF THE NIMONIC C-263 ALLOY DURING TURNING UNDER DIFFERENT MACHINING CONDITIONS**

Sesi Pengajian: **2021/2022 Semester 2**

Saya **TUAN NORLIZA HANIM BINTI TUAN HUSSIN (980624-03-6594)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syaratkegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☑ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:	Cop Rasmi:
KAMPUNG BENDANG BARU BUKIT PANAU 17500 TANAH MERAH, KELANTAN	
Tarikh: 29/6/2022	Tarikh: 29/6/2022

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Investigation on the Surface Roughness of the Nimonic C-263 Alloy during turning under different machining conditions" is the result of my own researchexcept as cited in the reference.

Signature : ……………………………………

Author's Name : TUAN NORLIZA HANIM BINTI TUAN HUSSIN

Date : 29th June 2022

APPROVAL

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

……………………………………………………………

(ASSOC. PROFESOR. DR. MOHD AMRI BIN SULAIMAN)

ABSTRAK

Kajian ini dijalankan pada penamat berkelajuan tinggi yang mengubah proses Nimonic C-263 Alloy untuk menilai integriti permukaan mesin dan membuat perbandingan nilai kekasaran permukaan (Ra) untuk keadaan kering dan banjir menggunakan sisipan karbida bersalut PVD. Kajian ini juga dijalankan untuk mencapai dua objektif iaitu untuk menentukan faktor-faktor penting kekasaran permukaan untuk kedua-dua keadaan (kering dan banjir) melalui analisis ANOVA dan terakhir untuk menyiasat nilai kekasaran permukaan Nimonic Alloy C263 di bawah keadaan kering dan banjir. Reka bentuk eksperimen untuk eksperimen ini adalah berdasarkan metodologi permukaan tindak balas (RSM) dalam mengenal pasti prestasi terbaik faktor-faktor penting. Reka bentuk Box-Behnken dipilih untuk mengatur parameter pemesinan. Parameter pemotongan yang telah dipilih dalam kajian ini adalah kelajuan pemotongan (60-120 m / min), kadar suapan (0.05-0.15 mm / rev), dan kedalaman potongan (0.3-0.5 mm). Nilai kekasaran permukaan diukur pada setiap 20mm di sepanjang permukaan mesin menggunakan penguji kekasaran permukaan mudah alih sehingga purata haus sayap, nilai Vb mencapai 0.2mm. Analisis ANOVA digunakan untuk mengenal pasti parameter pemotongan yang ketara ke arah tindak balas. Analisis ANOVA menunjukkan bahawa kadar suapan adalah faktor pemotongan yang paling ketara yang mempengaruhi kekasaran permukaan. Model regrasi telah dibangunkan untuk kekasaran permukaan melalui analisis ANOVA ini. Berdasarkan keputusan yang diperolehi, penggunaan penyejuk banjir menghasilkan kekasaran permukaan yang lebih baik daripada dalam keadaan kering. Di samping itu, hasilnya menunjukkan bahawa parameter optimum untuk kedua-dua keadaan pemesinan adalah kadar suapan.

ABSTRACT

This study was conducted at the high-speed finish turning the process of Nimonic C-263 Alloy in order to evaluate the surface integrity of the machined surface and make a comparison of the surface roughness (Ra) values for dry and flooded conditions using PVD coated carbide insert. This study was also carried out to achieve three objectives which are to determine the significant factors onto surface roughness for both conditions (dry and flood) through ANOVA analysis and lastly to investigate the surface roughness values of Nimonic Alloy C263 under dry and flood conditions. The experimental design for this experiment was based on the response surface methodology (RSM) in identifying the best performance of significant factors. The box-Behnken design was selected to arrange the machining parameters. The cutting parameters that had been selected in this study are cutting speed (60-120 m/min), feed rate (0.05-0.15 mm/rev), and depth of cut (0.3-0.5 mm). The surface roughness values were measured at every 20mm along the machined surface using a portable surface roughness tester until the flank wear average, Vb value exceeds 0.2mm. ANOVA analysis was used to identify cutting parameters that significantly towards the response. ANOVA analysis showed that the feed rate was the most significant cutting factor affecting the surface roughness. A regression model was developed for surface roughness through this ANOVA analysis. Based on the results obtained, the application of flooded coolants produced better surface roughness rather than in dry conditions. Additionally, the result showed that the optimum parameter for both machining conditions was the feed rate.

DEDICATION

The name of Allah, the Most Gracious and the Most Merciful

I dedicate this final year project to:

My beloved parents,

Tuan Hussin Bin Tuan Yacob and Rafiah Binti Noor

To my lovely siblings who always support me.

To my supervisor and lecturers who gives the guidance and motivation along my studies in Universiti Teknikal Malaysia Melaka (UTeM)

Thanks to everyone for giving me moral support, money, cooperation, encouragement, and also understanding.

Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah I manage to complete this final year project successfully and without difficulty. I want to thank my respected supervisor, Assoc. Prof. Dr. Mohd Amri Bin Sulaiman for the great mentoring, kind supervision, advice, and guidance as well as for exposing me to meaningful experiences throughout the study of this project.

Besides that, I would like to express my gratitude to my parents, and family members for always supporting me financially, mentally, and physically in achieving my goals. Big thanks to one of my younger sisters, Tuan Nor Faizah Binti Tuan Hussin for always being there for me at my lowest phase. Last but not least, I would like to give special thanks to my best friends, Noreen, Lim, Lee, and Choy as well as my fellow friends who gave me so much motivation and cooperation mentally in completing this report. They had given their critical suggestion and comments throughout my research. Thanks for the great friendship.

Finally, I would like to make an affectionate acknowledgment to all my colleagues and friends who had helped and supported me during my research studies directly or indirectly.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

PVD	-	Physical Vapor Deposition
CVD	-	Chemical Vapor Deposition
CO2	-	Carbon Dioxide
N2	-	Nitrogen
CNC	-	Computer Numerical Control
Ra	-	Surface Roughness
DOC	-	Depth of cut
HSM	-	High-Speed Machining
Wc	-	Tungsten Carbide
Co	-	Cobalt
TiC	-	Titanium carbide
TiN	-	Titanium nitrate
Al_2O_3	-	Aluminium oxide
TiAlN	-	Titanium aluminium nitrate
CBN	-	Cubic Boron Nitride
PCBN	-	Polycrystalline Cubic Boron Nitride
MRR	-	Material Removal Rate
DOE	-	Design of experiment
RSM	-	Response Surface Methodology
HV	-	Vickers Pyramid Number (Hardness)

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, since nickel-based alloys are extremely famous for their excellent attributes in terms of hardness at elevated hotness and high impervious to corrosion, the application of this type of material has been increasing day by day (Sreenivasa Rao & Venkaiah, 2015).

This study is carried out to investigate the machining conditions in turning the Nimonic C-263 Alloy. According (Ezilarasan et al., 2011b), Nimonic C-263 Alloy is extensively employed in aerospace, power generators, turbine blades as well as heat exchangers. However, as is known, the fabricating method of this material is quite difficult regarding its low thermal conduction and solidification criterion. This material, which is known as heat resistant, consists of alloy that acknowledges the dominant machine-like, ductility, and creep strength at high temperatures, high fatigue strength, and frequently superior corrosion and oxidation resistance at elevated temperatures (Vetri Velmurugan & Venkatesan, 2021).

The Nimonic C-263 alloy is used a lot in heavy industries because of its special properties (Thakur et al., 2014). On the other hand, this alloy is quite challenging to machine. Heat-resistant alloys called superalloys exhibit exceptional mechanical, ductility, and creep strength at high working temperatures, high fatigue strength, and often strong corrosion and oxidation resistance at high temperature (Venkatesan & Thakur, 2018). The experimental study and assessment of the machining requirements for turning the Nimonic C-263 alloy will be explored in more detail.

Turning is a sort of manufacturing process that include machining away excessive element to produce rotatable product parts. The turning process necessitates the use of a turning machine, a workpiece, a fixture, and a cutting tool. The workpiece is a pre-shaped piece of material that is secured to the fixture before being attached to the turning machine and rotated at high speeds. Even though multi-point tools are used in some operations, the cutter used is usually a single point cutting tool that is also fastened in the machine. The cutting tool feeds into the rotating workpiece and cuts material away in the form of small chips to create the desired shape.

The material of the workpiece involved in this study is Nimonic C-263 Alloy which is very suitable to be used in high temperature and high strength applications. According to M. Singh & Gangopadhyay (2017), Nimonic C-263 alloy, one of the age-hard enable nickel-based superalloys, contains a significant quantity of cobalt, chromium, and molybdenum, which improves corrosion and oxidation resistance. This type of material also has high strength, high corrosion resistance, good formability as well as high-temperature ductility.

Besides, the machine used in this study is CNC Lathe Machine and will be a focus on the turning process. The cutting tool that has been used in this study is PVD coated carbide insert. Coated carbide has been applied in a variety of applications because of the superior mechanical features of the material.

Next, this experiment will be undergone under flood and dry conditions. Lubricant and coolants are other terms for cutting fluid. It is commonly used in the machining process to improve surface integrity by lowering cutting temperature and pressure. It lubricates all tool, chip, and workpiece contact areas, reducing friction between mating surfaces (M. Singh & Gangopadhyay, 2017). Coolants also can prevent adhesion, abrasion, and diffusion wear, as well as heat softening of tool material, extending tool life. Hence, the variables examined by most of the researchers before are the depth of cut, feed rate, and cutting speed. Thus, the impact of various factors and their relationships towards cutting surface roughness has also been investigated in this study.

1.2 Problem Statement

In today's industrial industry, there is a tremendous demand for great accuracy, economical parts. As a result, an ample amount of research has been done on optimization, machining interpretation, surface roughness prognostication, and process optimization. In addition to modeling, the study and investigation of the effect of cutting parameters on the group of cutting force, tool wear, and surface roughness in the turning of aerospace element materials like the Nimonic C-263 alloy is critical to support development control organization actions in the turning of aerospace parts materials.

Because Nimonic C-263 alloys have high-temperature properties, they subject cutting tools to extreme heat, pressure, and abrasion, causing rapid flank wear, crater wear, and tool notching at the tool nose, as well as making them extremely difficult to machine, affecting dimensional accuracy and surface integrity (Sun et al., 2018).

Heat concentration at the cutting tool chip interface is caused by work hardening and limited thermal conductivity, resulting in thermomechanical stress. This, in turn, has an impact on tool life and results insignificant surface degradation (Ezilarasan et al., 2011a).

Even at high temperatures, Nimonic alloys exhibit a great degree of mechanical strength. While this may appear to be a significant benefit, it also means that tool wear is limited, causing excessive stress on the parts. Machining Nimonic alloys, as well as all Nickel-based alloys, is challenging for a variety of reasons (Jangali Satish et al., 2021).

Due to the limited heat conductivity of superalloy, high cutting temperatures are generated in the cutting zone. High tool wear is caused by high-temperature strength, hot hardness, and high cutting temperature, resulting in shorter tool life and poor surface integrity. Increased cutting temperature and pressure at high cutting parameters hurt the tool's condition and the surface quality of the machined component (M. Singh & Gangopadhyay, 2017).

Furthermore, lubricants and coolants that have been used on the machining zone significantly lower the cutting temperature. Various approaches have been used to ensure proper cooling and lubrication. The coolants and lubricants prevent the chip-tool contact from rubbing together and remove the heat created in the cutting zone. Mineral oils and water-based soluble oils are the most common cutting fluids utilized in many manufacturing industries. These oils endanger the environment and jeopardize workplace safety. Cutting fluids are known to be harmful to machinists' health and can occasionally slow down production. Depart of that, one of the main issues on surface finish issue is the surface roughness of the machined surface. Surface roughness might be affected due to the tool characteristic, machining condition, machining parameters and every of each possible reasons are needed to have a deep researched in enhancing the product surface quality.

Moreover, dry machining also gives problems in turning hard material. But, sometimes, although dry turning can be an excellent alternative, the lack of cutting oil caused excessive friction and heating during the machining process. The machined surface is damaged in dry machining due to the creation of Built-up-Edge (BUE) which caused by insert dragging across the surface of the machined component.

1.3 Objectives

Below are the objectives for this study:

i. To determine the significant factors onto surface roughness for both conditions (dry and flood) through ANOVA analysis.

ii. To investigate the surface roughness values of Nimonic Alloy C263 under dry and flood condition.

1.4 Scopes of the Research

The scope of this study is carried out to analyze the significant factors towards the surface roughness values by aid chart and diagram in differentiate values of Ra between dry and flooded conditions. next, this study also been done in comparing the surface roughness (Ra) values of the machined surface for both conditions. The workpiece that has been used in this study is Nimonic C-263 Alloy. So, this study is focused on that material workpiece to see how it reacts with the use of the cutting tool which is PVD coated carbide insert. The analysis of this study has been referred to by previous research. This study was conducted in high-speed turning machining in flooded and dry conditions as mentioned above. Rearrange the mathematical model of Ra for dry and flood also been studied in this research.

Besides, this study was focused on three cutting parameters which were cutting speed, feed rate and depth of cut. This experiment was conducted in various selected cutting parameters based on the response surface methodology (RSM). This experimental combination arrangement technique is guided by the Box-Behnken technique of RSM. RSM is a statistical method based on the multivariate nonlinear model that entails designing experiments to provide adequate and reliable response measurements, developing a mathematical model that fits the data obtained from the experimental design, and determining the optimal value of the independent variables that produce maximum or minimum response (Sharifi Pajaie & Taghizadeh, 2015).

All the results obtained was analyzed by using Analysis of Variance (ANOVA) analysis. Result obtained also will indicate the mathematical model of Ra for dry and flood conditions. ANOVA analysis was generally used to summarize the experiments that have been performed, also able to identify significant machining parameters and build empirical models for turning of Nimonic C-263 Alloy using PVD coated carbide.

1.5 Important of Study

In many engineering applications, measuring surface roughness is crucial. The quality of the surface finish can also influence a variety of life characteristics. In the research of surface integrity, surface roughness is thus regarded as one of the most important factors. The shape of the cutting tool and machining parameters are primarily responsible for surface roughness in the turning process. Furthermore, surface roughness is one of the most critical turning process responses since it impacts the machined component's fatigue strength, wear rate, corrosion resistance, and tribological properties.

Besides, surface finish and tool wear are the most important machining parameters to consider when estimating the turning's performance. These characteristics influence fatigue strength, surface integrity, dimensional precision, and corrosion resistance, all of which are essential for important aerospace applications. To obtain enhanced machining performance which is lower surface roughness and lower flank wear for varied combinations of workpiece and inserts, it is critical to optimize machining settings and environmental conditions (Jadhav et al., 2020a).

However, the development of forces and temperatures at the cutting zone, as well as deformation on the flank face and adhesion of the workpiece material, are all thought to be responsible for these surface conditions. Due to the pressure weld between the tool and the chip, which may randomly pluck and scratch the machined surface at a smaller value speed of cutting, hence, the chip may stick to the tool surface. Surface roughness is the mark left on the machined surface by the tool wedge's shape. The angle approach plan, edge of the cutting, nose radius as well as the feed rate all play a crucial role in surface roughness (Ezilarasan et al., 2011a).

Furthermore, through ANOVA analysis, a significant shear factor to the surface roughness can be determined. moreover, through this ANOVA analysis as well, it can develop an empirical model for the machined surface for flooded and dry cooling conditions. Based on these experiments, the obtained machined surface roughness was compiled in the design analysis of historical data to determine the optimal cutting conditions. Next, these optimal parameters are classified through experiments and the percentage of error is determined.

1.6 Organization of the Report/Thesis

Chapter 1: Introduction

This chapter is discussed about the background of the study. Other than that, this chapter also discusses the problem statement that has been identified through the previous research and observation. Next, it is followed by the objectives of this study that need to be achieved throughout this study and it also discusses the scope where it has been narrowed down the study area.

Chapter 2: Literature Review

This chapter is discussed about the fundamental theories concerning the research topic and preceding studies from academic journal and the internet. The current material handling equipment has also been explained in this chapter. The cutting parameters that have been done are also comprised. Lastly, the methods and results of the previous research have also been evaluated and described.

Chapter 3: Methodology

This chapter is discussed about the flow chart process of this experiment that will be carried out. It consists of what type of process will be carried out through this study. Next, this topic also will be finalized what is the cutting parameters that going to be applied in this experiment. Besides, this chapter also will be mentioned what is the method that will be going to use when carrying out this experiment. And lastly, the results of the experiment will be observed and planned for the next action.

Chapter 4: Results and Discussion

This chapter was discussed about the results of surface roughness value of the machined surface for both conditions. All the data and results were recorded. The most significant parameters affecting the surface roughness also been analyzed in this chapter.

Chapter 5: Conclusion and Recommendations

This chapter will conclude for the whole experiment and also some recommendations would be provided for the future studies.

CHAPTER 2

LITERATURE REVIEW

This chapter clarify the summary of related research on articles, journals, websites, and books that has been done by the researchers before. The theme that is covered in this part is turning, cutting parameter, feed rate, cutting speed, depth of cut, high-speed machining, machining in dry and flood conditions, cutting tool material, cemented carbide tool, coated and uncoated carbide, surface roughness, characteristic of surface roughness, surface topography, surface metallurgy and topology, material removal rate, Nimonic C-263 Alloy, design of experiment and response surface methodology.

2.1 Turning Process

Turning is a material removal process or a type of machining that is used to shape materials. A turning simple machine or lathe, as well as a workpiece, fixture, and cutting apparatus, are required for the turning process. The work item is fastened to the machine's spinning fixture and allowed to spin at high speeds. To make the required structure, the cutting tool swallows into the spinning workpiece and cut off away material in the form of small-scale chips.

In recent years, turning has shown to be an efficient machining process that has piqued the curiosity of experts looking for a replacement for grinding (Jadhav et al., 2020b). In the machining of hardened steels, hard turning is more effective and efficient than typical grinding procedures (Sivaraman & Prakash, 2017). Jadhav et al., (2019)