EXPERIMENTAL INVESTIGATION OF TOOL WEAR PROGRESSION IN TURNING OF NIMONIC C-263 ALLOY

MUHAMMAD FAIZ BIN AHMAD FAUDZI

B051820092

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

B051820092 BACHELOR OF MANUFACTURING ENGINEERING (Hons.) 2022 UTeM

EXPERIMENTAL INVESTIGATION OF TOOL WEAR PROGRESSION IN TURNING OF NIMONIC C-263 ALLOY

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

by

MUHAMMAD FAIZ BIN AHMAD FAUDZI

B051820092

971127-08-5649

FACULTY OF MANUFACTURING ENGINEERING

2022

UTeM

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **EXPERIMENTAL INVESTIGATION OF TOOL WEAR PROGRESSION IN TURNING OF NIMONIC C-263 ALLOY**

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

Saya **MUHAMMAD FAIZ BIN AHMAD FAUDZI (971127-08-5649)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan 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:
153, Laluan Keranji 1 Kampung Dato' Ahmad Said Tambahan 3, 30020, Ipoh, Perak

Tarikh: 14/07/2022

Cop Rasmi:
IR. DR. MOHAMAD RIDZUAN BIN JAMLI
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

Tarikh: 14/07/2022

*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 "Experimental Investigation of Tool Wear Progression in Turning of Nimonic C-263 Alloy" is the result of my own research except as cited in references.

Signature : ……………………………………………

Author's Name : MUHAMMAD FAIZ BIN AHMAD FAUDZI

Date : 30 JUN 2022

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………………………………………

(IR. DR. MOHAMAD RIDZUAN BIN JAMLI)

ABSTRACT

Because of its unique qualities, Nimonic C-263 Alloy is widely utilised in aircraft, gas turbine blades, power generators, and heat exchangers, among other applications. The materials are finding new uses in the fabrication of essential components for high-performance aviation gas turbine engines, partly because of their outstanding mechanical qualities that stay stable at high temperatures. According to a prior study, the most prevalent issue other researchers have run across while examining Nimonic C-263 Alloy is the cutting tool’s short life cycle and thermal degradation. Besides, the cutting tool's wear is the most common problem encountered throughout this procedure. This study aims to conduct an experimental investigation of the wear characteristics of tools when turning Nimonic C-263 Alloy. This research will focus on the experimental investigation and analysis of machining parameters while turning Nimonic C-263 Alloy with PVD coated inserts to predict their optimal values. Cutting speed, feed rate, and depth of cut were the parameters that were considered for the parameters. The indication of process performance, the cutting temperature, and tool wear will be monitored and recorded. Using Response Surface Methodology (RSM), an empirical model will be developed for predicting tool wear and heat generation. From the results, the highest tool life documented in the research is 19.25 minutes, while the least is 1.97 minutes. By comparing the experimental result with the theoretical value with an error of less than 10 per cent demonstrates that the mathematical model accurately predicted the tool life.

ABSTRAK

Kerana kualitinya yang unik, Nimonic C-263 Alloy digunakan secara meluas dalam pesawat, bilah turbin gas, penjana kuasa dan penukar haba, antara aplikasi lain. Bahan-bahan tersebut menemui kegunaan baharu dalam fabrikasi komponen penting untuk enjin turbin gas penerbangan berprestasi tinggi, sebahagiannya kerana kualiti mekanikalnya yang cemerlang yang kekal stabil pada suhu tinggi. Menurut kajian terdahulu, isu paling lazim yang dihadapi oleh penyelidik lain semasa memeriksa Nimonic C-263 Aloi ialah kitaran hayat pendek alat pemotong dan degradasi haba. Selain itu, kehausan alat pemotong adalah masalah yang paling biasa dihadapi sepanjang prosedur ini. Kajian ini bertujuan untuk menjalankan penyiasatan eksperimen tentang ciri haus alatan semasa memusing Nimonic C-263 Aloi. Penyelidikan ini akan memberi tumpuan kepada penyiasatan eksperimen dan analisis parameter pemesinan sambil memutarkan Nimonic C-263 Aloi dengan sisipan bersalut PVD untuk meramalkan nilai optimumnya. Kelajuan pemotongan, kadar suapan, dan kedalaman pemotongan adalah parameter yang dipertimbangkan untuk parameter tersebut. Petunjuk prestasi proses, suhu pemotongan, dan kehausan alatan akan dipantau dan direkodkan. Menggunakan Metodologi Permukaan Tindak Balas (RSM), model empirikal akan dibangunkan untuk meramalkan haus alat dan penjanaan haba. Daripada keputusan, jangka hayat alat tertinggi yang didokumenkan dalam penyelidikan ialah 19.25 minit, manakala paling sedikit ialah 1.97 minit. Dengan membandingkan keputusan eksperimen dengan nilai teori dengan ralat kurang daripada 10 peratus menunjukkan bahawa model matematik meramalkan hayat alat dengan tepat.

DEDICATION

Only

My beloved father, Ahmad Faudzi Bin Ramli

My appreciated mother, Noorliza Binti Ismail

Fauzan, Fasihah, Fahim, Fakhirah, and Fawwaz are some of my most cherished family members.

Thank you for your moral and financial support, as well as your cooperation and understanding.

Thank you very much and I will cherish each and every one of you forever.

ACKNOWLEDGEMENT

The most lavish praises and thanks go to Allah for allowing me to accomplish my final year assignment without incident in the name of the Most Gracious, The Most Merciful.

My supervisor for the duration of the project, Ir. Dr. Mohamad Ridzuan Bin Jamli, whom I admire.

This report would not have been possible without the encouragement and cooperation of my closest friends, notably Mohd Saiful and Ahmad Nazir, for their research help and financial assistance from Zulhilmi. Throughout my investigation, they offered insightful suggestions and remarks. I appreciate your friendship.

Last but not least, I want to thank everyone who contributed to this FYP report and apologise for not mentioning each individually.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PVD	-	Physical Vapor Deposition
CVD	-	Chemical Vapour Deposition
CNC	-	Computerized Numerical Control
(Ti,Al)N	-	Titanium Aluminum Nitride
SEM	-	Scanning Electron Microscope
XRD	-	X-Ray Diffraction
PCBN	-	Polycrystalline Cubic Boron Nitride
WC	-	Tungsten Carbide
IR	-	Infrared
EDX	-	Energy Dispersive X-Ray
DOE	-	Design of Experiments
RSM	-	Response Surface Methodology
ISO	-	International Organization for Standardization,
GAXRD	-	Glancing Angle X-ray Diffraction
MQL	-	Minimal Quantity Lubrication
HPC	-	High-Pressure Coolant
BUE	-	Built Up Edge
ANOVA	-	Analysis of Variance

LIST OF SYMBOLS

V_b	-	Average flank wear
$V_{b\ max}$	-	Maximum flank wear
° C	-	Degree Celsius
Mm	-	Milimeter
m	-	Meter
μm	-	Micrometer

CHAPTER 1

INTRODUCTION

Chapter 1 of this research will explain the background of the study regarding the investigation. Besides that, the problem statement, objective, scope, the significance of this study and organization of the report will also be explained in this chapter.

1.1 Background of Study

Due to their better mechanical qualities maintained at increased temperatures, nickel-based superalloys are finding expanded uses in producing essential components for high-performance aviation gas turbine engines (Ezilarasan et al., 2013). Nimonic C-263 is one of the most important alloys in nickel-based superalloys. Nimonic C-263 Alloy is a nickel-chromium-cobalt-molybdenum alloy that excels at high temperatures and has excellent strength. Precipitation hardening is another option for this metal. To avoid rusting, it shows its resistance to chemical degradation induced by the surrounding environment or other gas chemicals. However, because superalloys are very hot, the cutting tool is subjected to considerable pressure and strain and roughness from the material.

When cutting nickel alloys, the first consideration is whether cooling or lubrication is more important. When heat removal is critical, soluble water-based fluids are used in high-metal-removal-rate turning operations. Cutting fluid use saves money on tools and makes it simpler to maintain tight tolerances and preserve the surface qualities of the workpiece without causing damage (Sales et al., 2001). Flood coolant was used as the cutting fluid in this experiment converting nickel-based alloy. The use of flood coolant increased the tensile stress in the nearsurface layer and created a bigger compressive stress zone underneath it (Sharman et al., 2008). When machining at slower rates with lower cutting temperatures, flood cooling is an excellent way to extend tool life. However, when cutting temperatures rise over a certain point, the fluid may evaporate and create a high-temperature steam barrier, preventing most of the fluid from entering the cutting zone. Aside from tool wear, the heat produced during cutting affects machining productivity, processed surface quality, accuracy, and other machining output characteristics (Nedic´ & Eric´, 2014). As a result, it is critical to investigate, measure, and understand the levels and distributions of cutting temperature inside the tool and workpiece. Based on this information, optimal settings, working regimes, process quality, productivity, and economy, as well as tool stability, may be determined.

1.2 Problem Statement

According to a prior study, the most prevalent issue other researchers have run across while examining Nimonic C-263 Alloy is the cutting tool's short life cycle and thermal degradation. Demand for super-finished components in aviation has led aircraft manufacturers to investigate innovative machining methods for superalloys at a fast cutting rate, with excellent surface quality, and at a cheap cost (Bisaria & Shandilya, 2019). Cutting procedures are often used in the manufacturing business, and they need the use of cutting instruments, workpieces, and chips. The cutting tool's wear is the most common problem encountered throughout this procedure. Tool wear is the gradual degradation of cutting tools due to prolonged usage. Tool wear impacts the machining process because it affects the surface roughness of the cutting tool. This impact will cause crater wear, flank wear, and cutting-edge chipping, among other forms of wear. Aside from that, the wear of the cutting tool will impair the workpiece's dimensional correctness. As a consequence, the size of the generated component may be changed, and the element's geometry may be jeopardized. Tapered workpieces may result from cylindrical turning, for example, due to excessive cutting tool wear.

Because most mechanical energy utilised to remove materials is heat, machining produces high temperatures in the cutting zone (Ghani et al., 2016). When the cutting speed is increased, the temperature reading increases as well. This is because the heat generated during the operation is swiftly increased. Besides that, the microstructure of alloy will also change due to high heat generated while machining generated residual stresses cause a further reduction in the component's fatigue life (Seleznev et al., 2021). Utilizing heat and wear-resistant cutting tool materials, such as carbides, coated carbides, and high-performance ceramics, as well as the careful selection of process parameters and application of cutting fluid, it is possible to reduce the damaging effects of high cutting temperatures in an industrial setting.

1.3 Objective

The objectives of this study are:

i. To evaluate parameter effect on tool life while turning the Nimonic C-263 Alloy using PVD coated inserts.

ii. To predict the tool life progression of the cutting tool using the mathematical model from the ANOVA analysis.

iii. To validate the cutting parameter of the statistical model of the tool life

1.4 Scope

The experimental investigation is turning the Nimonic C-263 Alloy using Physical Vapour Deposition (PVD) coated inserts. Besides that, the objective of this study is to examine the impact of flood coolant in machining Nimonic C-263 alloys and tool wear on various cutting speeds and cutting tool life. Furthermore, this study only involves in Nickel-based alloy family. These experiments were performed under flood coolant conditions by using water-based fluids. While turning machining in coolant, the performance of cutting tools that have been coated, tool wear progressions of the tool life will be investigated. Cutting speed, feed rate, and cut depth were analyzed as machining parameters for this experiment. Response surface methodology (RSM) was utilized to determine the best cutting parameter in this investigation.

1.5 Significant of Study

The outcomes of this study will help to solve the current industry problem. Studying tool wear characteristics on Nimonic C-263 Alloy is an essential component in the operations of many manufacturing companies. By showing the type of wear that will occur when machining the superalloy, the manufacturing company will provide a careful procedure and step to reduce the wear of the cutting tool and increase its lifespan. Besides that, this study is also critical because it will investigate the cutting speed, feed rate and depth of cut for the material so that the manufacturing companies can make a guideline to their worker about the machining parameters when cutting the Nimonic C-263 Alloy.

1.6 Organization of Report/ Thesis

The performance of coated carbide inserts in turning Nickel Based Alloy under flood conditions was the main focus of this paper. The introduction of the Nickel-based alloy will be discussed in Chapter 1 of this study, as well as the study's research background, problem statement, research purpose, the scope of research, and thesis structure. Chapter 2 covers the turning process, the nickel-based alloy, the cutting tool material, the tool failure mechanism, the reasons of tool wear, the processes of tool wear, the tool life, the cutting fluid, the experimental design, the most recent literature reviews, and previous research studies.Chapter 3 discusses the equipment, experimental methodologies, and cutting conditions used in Nickel-based Alloy turning. Chapter 4 discusses the effect of coated carbide on tool wear and life. Additionally, this chapter discusses tool wear processes and ANOVA analysis. Finally, Chapter 5 contains a summary and conclusion to this study.

1.7 Summary

In summary, nickel-based alloy is one of the alloy that is difficult to machine alloy which many manufacturing companies discover while machining this sort of material. Therefore, it will limit the lifespan of the cutting instrument. By completing this investigation, this problem could marginally lessen the tool wear. This is crucial since it will enhance the output of the material by the firm, especially in the manufacturing industries.