Faculty of Manufacturing Engineering

OPTIMIZATION OF CARBIDE TOOL PERFORMANCE UNDER DRY CONDITIONS IN TURNING TITANIUM ALLOY TI-6A-4V ELI

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DECLARATION

I declare that this thesis entitled "Optimization of carbide tool performance under dry conditions in turning titanium alloy Ti-6A-4V ELI" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature	:	…………………………………
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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion, this dissertation/report is sufficient in terms of scope and quality as partial fulfillment of Master of Manufacturing Engineering (Quality System Engineering).

Signature : ....

Supervisor Name : PM. DR MOHD AMRAN SULAIMAN

Date : 8/2/2023

DEDICATION

My master project report is dedicated to my family and many friends. I am very grateful to my loving parents, Adam bin Abdul Majid, and Afidah Binti Ahmad Zaidi, for their words of support and push for persistence. Muhammad Afiz bin Adam and Nurul Asyiqeen Binti Adam, my siblings, have never left my side and are extremely dear to me. I also dedicate my master project report to my numerous friends and family members who have been so encouraging throughout the process. I shall be eternally grateful to them, particularly Roslina Aida Binti Rahimi and Siti Nur Hidayah Binti Husni for their assistance in developing my manufacturing skills and knowledge, for the many hours of proofreading, and for assisting me in mastering the master projects. I dedicate this work to my family, my master's project supervisor, and my closest friends Muhammad Huzaifah bin Mohamad, Muhammad Farhan bin Saadon, and Anisa Binti Adnan for their support during the master's program.

ABSTRACT

The purpose of this research was to look into the tool life performance of uncoated carbide under dry settings, to find the best parameters for carbide tool performance under dry conditions, and to investigate the tool wear behavior under dry conditions. The notion of tool life is regarded to be the cutting time necessary for a tool to achieve its tool life standards. In this study, uncoated tungsten carbide inserts (CNGG 120408-SGF H13A) will be employed to convert workpiece titanium alloy Ti-6AL-4V ELI (extra low interstitial). Titanium alloys have been widely employed in a wide range of applications, including aerospace, automotive, medical, and chemical sectors. This is owing to the high strength-to-weight ratio, strong fracture resistance, and improved corrosion resistance of titanium alloy. Titanium alloys, on the other hand, are challenging materials to produce even at high temperatures. It has a low elastic modulus, a low heat conductivity and is readily chemically reacted with the material of cutting implements. Based on previous research (Shafi'e, 2017), a two-level Factorial design was utilized to arrange the cutting parameters of 100 to 140 m/min cutting speed, 0.15 to 0.20 mm/rev feed rate, and constant depth of cut (0.35 mm). The progression of flank wear will be monitored using an optical microscope. The data will be collected for each 20 mm of the workpiece until flank wear (Vb) reaches the tool life criterion, at which time they will be replaced (International Standard ISO 3685). As an expected result, maximum tool life (3.97 minutes) is achieved during dry machining at a cutting speed of 100 m/min and a feed rate of 0.15 mm/rev.

PENGOPTIMALKAN PRESTASI ALAT KARBIDA DALAM KEADAAN KERING DALAM MENULIS ALOI TITANIUM TI-6A-4V ELI

ABSTRAK

Tujuan penyelidikan ini adalah untuk melihat prestasi hayat alat karbida tidak bersalut di bawah tetapan keadaan kering, untuk mencari parameter terbaik untuk prestasi alat karbida dalam keadaan kering, dan untuk untuk menyiasat tingkah laku haus alatan dalam keadaan kering. Pengertian hayat alat dianggap sebagai masa pemotongan yang diperlukan untuk alat mencapai standard hayat alatnya. Dalam kajian ini, sisipan tungsten karbida tidak bersalut (CNGG 120408-SGF H13A) akan digunakan untuk menukar aloi titanium bahan kerja Ti-6AL-4V ELI (interstisial rendah tambahan). Aloi titanium telah digunakan secara meluas dalam pelbagai aplikasi, termasuk sektor aeroangkasa, automotif, perubatan dan kimia. Ini disebabkan oleh nisbah kekuatan berat yang tinggi, rintangan patah yang kuat, dan rintangan kakisan yang lebih baik daripada aloi titanium. Aloi titanium, sebaliknya, adalah bahan yang mencabar untuk dihasilkan walaupun pada suhu tinggi. Ia mempunyai modulus anjal yang rendah, kekonduksian haba yang rendah, dan mudah bertindak balas secara kimia dengan bahan alat pemotong. Berdasarkan kajian lepas (Shafi'e, 2017), reka bentuk Faktorial dua peringkat telah digunakan untuk menyusun parameter pemotongan 100 hingga 140 m/min kelajuan pemotongan, 0.15 hingga 0.20 mm/rev kadar suapan, dan kedalaman pemotongan malar (0.35 mm). Perkembangan haus rusuk akan dipantau menggunakan mikroskop optik. Data akan dikumpul untuk setiap 20 mm bahan kerja sehingga haus rusuk (Vb) mencapai kriteria hayat alat, dan pada masa itu ia akan diganti (Piawaian Antarabangsa ISO 3685). Seperti hasil yang dijangkakan, hayat alat maksimum (3.97 minit) dicapai semasa pemesinan kering pada kelajuan pemotongan 100 m/min dan kadar suapan 0.15 mm/rev.

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LIST OF ABBREVIATIONS

Ae	-	Radial depth of cut
Ap	-	Depth of cut
AM	-	Additive manufacturing
ANOVA	-	Analysis of Variance
CBN	-	Cubic boron nitride
CC	-	Coated carbide
CCS	-	Conventional cooling system
CFRP	-	Carbon fiber reinforced polymer
CL	-	Cryogenic lubrication
CNC	-	Carbon Nano Fiber
CNF	-	Computer Numerical Control
CSR	-	Chip serration ratio
CVD	-	Chemical vapor deposition
CWMJ	-	Cold-water mist Jet
DMLS	-	Direct metal laser sintering
DOE	-	Design of Experiment
ELI	-	Extra Low Interstitial
Fc	-	Cutting Force
Fr	-	Radial Force
Ft	-	Thrust Force
Fz	-	Feed per tooth
HPC	-	High-pressure cooling
HPCF	-	High pressure coolant at flank face
HPCR	-	High pressure coolant at rake face
HPCS	-	High-pressure coolant system
LMD	-	Laser metal deposition
Kr	-	Crater Wear

KT	-	Cutting Edge Length
PCBN	-	Polycrystalline cubic boron nitride
PCD	-	Polycrystalline diamond
PVD	-	Physical vapor deposition
SLM	-	Selective laser melting
SQCL	-	Small quantity cooling lubrication
SQL	-	Small quantity qubrication
UCC	-	Uncoated carbide
Vc	-	Cutting speeds
Vb avg	-	Average Flank Wear
Vb max	-	Maximum Flank Wear

LIST OF SYMBOLS

m/min	-	Metre per Minute
mm	-	Millimetre
mm/rev	-	Millimetre per Revolution
N	-	Newton
%	-	Percentage
wt %	-	Chemical Composition
kW	-	Kilowatt
rpm	-	Rotation per Minute
Kg	-	Kilogram
J/kg K	-	Joule per Kilogram Kelvin
°C	-	Degree Celsius
W/m°C	-	Watt per Metre Celsius
W/mK	-	Watt per Metre Kelvin
m/s	-	Metre per Second
kg/m3	-	Kilogram per Metre Cube
Mpa	-	Mega Pascal
Gpa	-	Giga Pascal
HRC	-	Rockwell Hardness Scale
Mpa-m1/2	-	Mega Pascal-square root Metre
O	-	Degree

CHAPTER 1

INTRODUCTION

This chapter offers a brief overview of the project background on the Tool Performance of Uncoated Tungsten Carbide Insert During Turning Titanium Alloy Ti-6Al-4V ELI in Dry Conditions. Furthermore, this chapter will discuss the background information, problem statement, objective, necessity of study, and research arrangement.

1.1. Background information

Machinability refers to how easily a workpiece can be machined under specified operating parameters such as cutting speed, feed rate, and depth of cut. A workpiece's machinability is determined by evaluating the cutting tool life, machined surface quality, and component forces during cutting mentioned by (M. Sulaiman et al., 2014a). This kind of titanium alloy is machined using various cutting methods such as milling and turning. Turning is a machining technique that removes materials from a workpiece using a single-edge cutting tool to produce a cylindrical form or a complex surface profile (Groover, 2020). High-speed machining (HSM) is a contemporary technology that improves the efficiency, precision, and quality of workpieces while also lowering costs and machining time as compared to traditional cutting. The method is 5–10 times faster than traditional machining at specific cutting rates.

(M. Sulaiman et al., 2014a) have stated titanium and titanium alloys are two of the numerous alloy materials that have been produced and are extensively employed, particularly in aerospace, automotive, offshore industries, medicinal materials, oil exploration, and nuclear storage. Titanium alloy is a complex and costly metal. It has a unique strength-weight and resistance to cracking at high temperatures; decreased chemical characteristics; high-temperature wear and corrosion resistance; and longer life. It is also appropriate for use with composite constructions. A Ti-6Al-4V extra low interstitial (ELI) alloy was employed in this study, which has a better purity grade than the ATI Ti-6Al-4V alloy. Because of its low oxygen, carbon, and iron content, this grade has high strength and depth hardening ability. It is used in biomedical applications like surgical tools and orthopedic implants. It is also used in the aerospace and maritime industries.

Cemented carbide is a hard substance that is widely used in cutting tool materials and other industrial applications. It is made up of tiny carbide particles that are glued together to a composite by a binder metal. The aggregate in cemented carbides is often tungsten carbide (WC), titanium carbide (TiC), or tantalum carbide (TaC). In industrial applications, the terms "carbide" or "tungsten carbide “commonly apply to these cemented composites. Carbide cutters, in most cases, provide a superior surface quality on the item and allow for quicker machining than high-speed steel or other tool steels. Carbide tools are more resistant to heat at the point of cutter-workpiece contact than ordinary high-speed steel tools (which is a principal reason for the faster machining). Carbide is usually best for cutting rigid materials like carbon steel or stainless steel, as well as when other cutting tools would wear out faster, such as during high-volume production runs.

To obtain high product quality, it is critical to detect tool wear. Aside from that, early manufacturing process planning, increasing product quality, and computer-assisted process planning are critical. The present work studies the optimization of carbide tool performance under dry conditions in the titanium alloy ti-6al-4v Eli, at various values for speed, feed, and depth of cut, using experiments. The temperature produced and the force applied at the tool's cutting edge has the most significant impact on tool life. Changing the cutting speed, feed rate, and depth of cut parameters will have a direct impact on the cutting force and temperature produced toward the end of the tool life. The goal of this experiment is to investigate the tool life during the turning of titanium alloy under various conditions. Furthermore, uncoated tungsten carbide insert cutting speeds range from 0–100 m/s to cut titanium alloy under dry conditions.

1.2. Problem Statement

Because of the harsh operating environment of aviation engines, improvements to aircraft engines that rely on material qualities have been made in recent years. Among all the options, titanium alloy has emerged as one of the most valuable materials in the aircraft sector. Titanium alloy has a very high strength-to-weight ratio, making it a lightweight material with excellent strength. Furthermore, it has exceptional strength at high temperatures, allowing it to withstand the aircraft engine environment. Titanium, on the other hand, is categorized as a difficult-to-cut material due to its intrinsic features, such as its limited thermal conductivity, which raises the temperature at the tool-work-piece interface, affecting tool performance substantially.

The second issue is that its strong chemical reactivity creates material bonding and chip evacuation issues, which often result in catastrophic tool failure. Finally, although its great strength at raised temperatures has been stated as a positive, it requires exceptionally high cutting forces and power, which causes various issues during the machining process. As a result, machining titanium alloy has become a critical problem in both the industrial and academic fields. Turning is regarded as a key technology not only because it quickly removes undesired parts of materials but also because it can make almost all types of contour surfaces smoothly.

It is, nevertheless, a cutting process with variable chip load, pressures, and heat production. Rake and clearance angles vary with distance from the milling tool tip along the turning tool edges. As a result, analyzing the turning process and turning tool performance is always a difficult task. Because the material is difficult to cut or the available speed is limited, turning titanium alloys has attracted attention. Because titanium alloys have limited thermal conductivity, most of the heat produced during the cutting operation is transferred to the tool rather than the chips or workpiece. The high temperature in the tool weakens its characteristics, generates thermal stress, and causes severe tool damage. The experimental technique is still the most often used way to examine tool performance in the titanium turning process, with several research focusing on testing for various cutting circumstances.

1.3. Objective

- To investigate the tool life performance of uncoated carbide under dry conditions.
- To obtain optimum parameters of carbide tool performance under dry conditions.
- To investigate the tool wear behavior under dry conditions.

1.4. Scope of Project

This study focuses on cutting tool performance (tool life) and tool wear pattern in turning titanium alloy Ti6Al-4V under dry conditions. The goal of this research was to maximize the cutting tool life performance and wear pattern investigation in the turning of Ti-6Al-4V Extra Low Interstitials (ELI) under dry conditions utilizing an H13A uncoated carbide cutting tool. The result will also be supported by a critical analysis of past research. To meet the experiment's goals, a computer numerical control (CNC) lathe machine was employed in the turning procedure. Cutting parameters considered include cutting feed rate, cutting depth, and cutting speed. While the depth of cut remains constant, the feed rate and cutting speed will vary.

1.5. Importance of Study

Titanium alloys (Ti-6Al-4V) have been used in a wide range of applications, notably in aerospace, automotive, chemicals, and medicine, due to their high strength-to-weight ratio, excellent resistance to fracture, and remarkable anti-corrosion properties. On the other hand, Ti-6Al-4V is difficult to machine even at high temperatures because it has poor heat conductivity and elastic modulus and may chemically react with the uncoating on the cutting tool. Wear is one of the unavoidable issues in the machining process. The tool performance under dry machining conditions must be explored in order to characterize the interaction of carbide inserts with titanium alloy. Research must be done on cutter parameters like cutting speed, feed rate, and depth of cut to find out how carbide tools work best in dry conditions.

1.6. Organizational Report

Chapter 1 discusses the experiment's beginning. It includes the background of the study, problem statement, objectives, scope of the study, and significance of the study.

This study's literature review is covered in Chapter 2. It includes a review of turning machining, dry machining, and tool performance.

Chapter 3 discusses the project's methods. It includes a flow chart, literature review, and full factorial method.

This research's findings and conclusions are presented in Chapter 4. This study's data will be compiled and analyzed.

Chapter 5 discusses the research's findings and recommendations for future improvement.

CHAPTER 2

LITERATURE REVIEW

This chapter includes a review of the literature on the tool performance of carbide inserts while turning titanium alloys under dry circumstances. This literature study was shown to conclude this research. This chapter covers machining operations, titanium alloy (Ti – 6AL – 4V – ELI), cutting conditions (dry), uncoated tungsten carbide, tool wear behavior, tool life, and experiment design approach.

2.1 Machining Process

Machining is a subtractive manufacturing technique that includes the removal of material from a workpiece, often in the form of chips. Material is removed from a workpiece during machining using either a cutting tool or an energy source. Material removal in classical machining is followed by the generation of chips, which is performed by the employment of a cutting tool with a cutting edge (s). Nontraditional machining (NTM) methods, on the other hand, are chip-less material removal procedures that entail the utilization of energy for material cutting. Turning, drilling, milling, shaping/planing, broaching, and grinding are examples of classic machining processes as stated (Huda, 2020).

Machining may be thought of as a system made up of the workpiece, the cutting tool, and the equipment (machine tool). There is a relative motion between the tool and the work in machining; the main motion is termed cutting speed, and the secondary motion is called a feed. There are three main cutting conditions in general: (a) cutting speed, (b) feed, and (c) depth of cut. Cutting speed is the greatest of a cutting tool's or workpiece's relative velocities. In a turning machining process, for example, the surface speed of the workpiece is the cutting speed (v), which is commonly represented in m/min (see Figure 2.1). Feed (f) is the distance