UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE OF CVD COATED CARBIDE TOOL BY OPTIMIZING MACHINING PARAMETERS DURING TURNING TITANIUM ALLOY Ti-6Al-4V ELI IN FLOODED CONDITION

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

by

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DECLARATION

I hereby, declared this report entitled "Performance of CVD Coated Carbide Tool By Optimizing Machining Parameters During Turning of Titanium Alloy Ti-6Al-4V ELI in Flooded Condition" is the results of my own research except as cited in references.

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APPROVAL

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 (Manufacturing Process) (Hons.). The member of the supervisory is as follows:

....

(Dr Mohd Amri bin Sulaiman)

ABSTRAK

Proses melarik melibatkan proses membuang bahagian benda kerja yang berpusing menggunakan mata pemotong tunggal untuk membentuk silinder ataupun profil yang rumit. Dalam kajian ini, mata pemotong karbida yang disalut menggunakan kaedah Pemendakan Wap Kimia (CVD) telah digunakan untuk proses melarik Titanium Alloy Ti-6AL-4V ELI. Titanium alloy banyak digunakan didalam industri seperti aeroangkasa, automotif, perubatan dan lain-lain. Ini kerana sifat unik bahan tersebut iaitu nisbah kekuatan dan berat yang tinggi, ketahanan tinggi terhadap kepatahan, dan ketahanan yang tinggi terhadap karat. Walaubagaimanapun, titanium alloy adalah bahan yang mempunyai kebolehmesinan yang amat rendah walaupun pada suhu yang tinggi. Ia mempunyai pengaliran termal yang rendah, modulus elastik yang rendah dan mudah untuk bertindakbalas secara kimia dengan mata pemotong. Objektif kajian ini adalah untuk menyiasat prestasi mata pemotong semasa proses melarik titanium alloy Ti-6AL-4V ELI menggunakan mata pemotong karbida (CVD) dibawah keadaan banjir. Rekaan eksperimen kajian ini adalah berdasarkan kaedah "Factorial". Rekaan "Two Level Factorial" telah dipilih untuk menyusun halaju pemotongan didalam julat 100-140m/min, kadar suapan 0.15-0.20mm/rev dan kedalaman pemotongan malar(0.35mm). Haus rusuk diukur menggunakan mikroskop. Nilai haus direkodkan selepas setiap sesi pemotongan sehingga nilai haus rusuk mencapai kriteria jangka hayat mata pemotong (International Standard ISO 3685). Berdasarkan keputusan yang diperoleh, adalah diketahui bahawa halaju pemotongan dan kadar suapan yang rendah menghasilkan jangkahayat mata pemotong yang lebih panjang manakala sebaliknya pada halaju pemotongan dan kadar suapan yang tinggi. Berdasarkan analisis ANOVA, halaju pemotongan merupakan faktor yang lebih signifikan berbanding kadar suapan. Pemodelan matematik telah dijana dan ralat antara eksperimen dan model adalah 19%. Respon optimum telah didapatkan pada halaju 100m/min dan kadar suapan 0.15mm/rev dengan jangkahayat mata pemotong 15.43 minit manakala jangkahayat pemotong tersingkat adalah 4.07 minit pada kelajuan 140m/min dan kadar suapan 0.20mm/rev.. Ralat pengoptimuman antara eksperimen dan model adalah 0.19%. Daripada kajian ini, didapati bahawa walaupun titanium aloy mempunyai kebolehmesinan yang rendah, terdapat parameter yang sesuai untuk menghasilkan jangka hayat mata pemotong yang panjang.

ABSTRACT

Turning process involves the removal of material from a rotating workpiece with a single cutting tool to form a cylinder or intricate profile. In this research, coated carbide tools by Chemical Vapor Deposition,(CVD) were used in turning workpiece titanium alloy, (Ti-6AL-4V ELI). Titanium alloys have been used widely in many applications especially in aerospace, automotive, medical and chemical. This is because high strength to weight ratio, high fracture resistance, and excellent corrosion resistance of titanium alloy. However, titanium alloys have poor machinability even at elevated temperatures. It has low thermal conductivity, low elastic modulus and easy to react chemically with the cutting tools material. The objective of this study is to investigate the performance of cutting tools in turning Ti-6AL-4V ELI using CVD coated carbide tool in flooded condition. Experimental design of this study is based on Factorial method. Two Level Factorial design was selected to arrange the cutting parameters of cutting speed with range of 100 to 140 m/min, feed rate with 0.15 to 0.20 mm/rev, and depth of cut is constant at 0.35 mm. Flank wear was measured using a three axis microscope. The values were recorded for each length of the workpiece until flank wear (V_b) reached the tool life criterion followed by International Standard ISO 3685. From the result obtained, it is found that lowest cutting speed and feed rate resulted in longer tool life while highest cutting speed and feed rate resulted in a much shorter tool life. Based on the ANOVA analysis, cutting speed is the most significant factor followed by feed rate. Mathematical modeling was developed and the error between experimental results and generated model is 19%. The optimum responses are obtained at cutting speed 100m/min, feed rate 0.15 mm/rev and this give out the longest tool life of 15.43 minutes while shortest tool life, 4.07 minutes was obtained at cutting speed of 140m/min and feed rate 0.20 mm/rev. The error of optimization between experimental and model is 0.19%. From this research, even though titanium alloy, Ti-6Al-4V are considered as material with poor machinability, there are suitable cutting parameter available to give out the longest tool life and reducing machining cost.

DEDICATION

To my beloved parents, Subari bin Hanapi and Junaidah binti Yusof, without whom I will not be where I am now.

To my lovely siblings,

Nur Syazwani binti Subari,

Nur Syafiqah binti Subari,

Muhammad Syazwan bin Subari.

To all my highly esteemed lecturers for their continous guidance and motivation

To all my friends, for their support and encouragement

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“Bismillahirrahmanirrahim”

In the name of Allah, the most gracious, and most merciful...

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CHAPTER 1
INTRODUCTION

This chapter explains the introduction of the research on “Performance of CVD Coated Carbide Tool By Optimizing Machining Parameters During Turning of Titanium Alloy Ti-6Al-4V ELI in Flooded Condition. In extension, this chapter will elaborate on the problem statement, objectives and scopes of the research.

1.1 Background

Manufacturing industries has forever been an ever-changing and rapid-developing environment. A handful of research and experiments have been made to improve the industry in general and this includes research on cutting tool. This report will discuss entirely on the research of the cutting tool performance in improving the quality and usage method of the cutting tool itself which will be enlighten in the next chapters. Different cutting tool characteristics such as types, material, and shape will ultimately serves for various applications. In example, for a cutting tool to obtain features such as long lifespan during service, it should possess a certain aspects such as hardness, toughness and high wear resistance. Chemical Vapour Deposition (CVD) carbide tool are one of the most used cutting tool in the industry.

In usual cases of cutting tool usage, it will be used until they reach their maximum tool wear which can vary in the duration of the usage. Prior research that has been done regarding the cutting tool life always focuses on the elimination or minimization of the tool wear. The improvement of the cutting tool’s wear will result in cost reduction and quality improvement during machining. Coated carbide tools are used extensively in the metal industry especially for material removing process such as turning operations. There are several causes that permitted tool failure in the course of machining that uses carbide cutting tool under normal cutting condition and one of it is flank wear. Investigations were carried out by Kishawy et al. (2005) in order to study the tool wear on some cutting tool materials. It is concluded from the research that flank wear criterion can be found by using the plotted tool life and in addition to that, discover that by using high speed in turning operation will ultimately lead to a shorter tool life.

Another aspect that needs to be considered in affecting the cutting tool life is the material to be machined. Carbide cutting tool can machine a great deal of material types and this includes some super alloy such as Titanium and Titanium Alloy. These types of material are difficult to be machined due to its fabulous characteristics such as high specific strength or are often known as strength-to-weight ratio which is uphold at elevated temperature, their resistance to fracture is very high and excellent corrosion resistance even when subjected to high heat or thermal activity (Ezugwu and Wang, 1997; Ezugwu, 2005).

Austenitic matrix is among the common characteristic of super alloys. This type of material usually utilized in the aerospace or aviation industry possess a certain disadvantage in their characteristic that offers rapid work hardening, responsiveness to the material of cutting tool which will result in the build-up edge and welded to the cutting tool. Low thermal conductivity of these type of material is also another disadvantage that is being displayed where it will surely deform the surface quality and this is worsen by the existence of abrasive carbide in the microstructures.(Che Haron et al., 2001; Ezugwu, 2005). The major requirements to the materials for the aerospace and aircraft industry are due to their ability to maintain their high strength at elevated temperature, fracture resistant characteristics and high resistance for corrosion. However, titanium alloys described as a difficult to machine materials due to their high strength at high generated temperatures, relatively low modulus of elasticity, low thermal conductivity and high chemical reactivity.

Turning process have forever been a dominant force in the machining industry where it specialized in machining rotating cylindrical parts by using a single-point cutting tool thus removing material. The basic process of the turning operation is the movement of the cutting tool is fed in linear parallel with the direction of the spindle rotation and lead to the material removal. In the effort of optimizing the turning operation, it is known that the selection of parameter is essential in ensuring an economical machining operation. Parameters value such as cutting speed value, feed rate value and depth of cut is the usual elements to be modified and the economics of machining can be computed by the productivity, manufacturing cost per part or any other suitable criteria.

1.2 Problem Statement

In titanium alloy machining, CVD carbide cutting tool are the types of cutting tools that are frequently used. However, due to the hardness of the titanium alloy and the nature of it to be difficult to machined, the cutting tool wear are fast and extensive. The friction between the machined surface and the cutting tool is one of the main causes that contribute to the wear mechanism on the flank of a cutting tool. This will ultimately become the predominant role to determine the tool life. Predicting the tool wear, tool life and tool failure are the most important subject to be discussed as it will affect machining costs and quality. It is safe to assume that tools with slower rate of wear will have a longer and more predictable lifespan in service.

Tool wear is inevitable in machining. There have been quite a handful of methods to decrease the effect of tool wear on cutting tools. One of it includes surface treatment on the cutting tool. Another way in optimizing the tool life is by studying the tool wear behaviour and controlling the machining parameters. According to Schneider et al. (2005) the optimum tool is not necessarily to be expensive and not always the same tool that was used for the job last time but the best tool is the one that has been carefully chosen to get the job done quickly, efficiently and economically. This mean, it is necessary to characterize specific cutting tool and work-piece combination to understand the interaction between machining parameters and tool wear performance.

Stephenson and Agapiou, (2005) stated that an understanding of tool life requires an understanding of the ways in which tools fail. Broadly tool failure may result from wear, plastic deformation or fracture. Tool wear may be classified by the region of the tool affected or by the physical mechanisms which produces it. The dominant types of wear in either case depend largely on the tool material. Tools deform plastically or fracture when they are unable to support the loads generated during chip formation. It is often possible to predict tool wear rates based on a test data or physical consideration, but this does not translate into a prediction of tool life in a general sense, since tool life depends strongly on part requirements.

1.3 Objectives

The objectives of this study are:

i. To study the influence of machining parameters to the tool wear of CVD carbide tool during turning of Ti-6Al-4V ELI under flooded condition.
ii. To define optimum process parameter settings to maximize tool life of CVD carbide tool.
iii. To develop a mathematical modelling of tool life.

1.4 Scope

This study only focuses on tool wear characterization of CVD carbide tool in turning the titanium alloy Ti-6Al-4V ELI with 32 HRC / 317 HV. The type of tool wear to be analysed is flank wear while the machining process is a single point turning operation with medium speed cutting range and with coolant involved. The machining parameters evaluated are cutting speed, feed rate and depth of cut. The cutting speed and feed rate will vary while depth of cut will be constant. The value of parameters and types of cutting tool are discussed in Chapter 3.

CHAPTER 2
LITERATURE REVIEW

In this chapter, every aspect that will be involved in this research will be discussed and elaborated extensively by the guidance of prior research by the previous researcher. The aspects to be discussed includes the material itself which is titanium (Ti-6AL-4V-ELI), the basic theory of turning process This review covers work-piece materials, turning operation, cutting condition (no coolant or dry), types of cutting tool, types of tool wear, and the design of experiment methods.

2.1 Titanium

Titanium is a type of metal which shows a high strength-weight ratio which is maintained at elevated temperature and possess an outstanding resistance towards corrosion. These properties and characteristics of the titanium are the main reason that causes the swift growth of the titanium industry. Aerospace is one of the major industries that titanium has contributed to, involving excessively in both the airframe and engine components. Titanium is also used in other industry besides the aerospace industry. It has been known that titanium also contributed to industries such as marine, chemical and electronics. An example of the application of the titanium in marine industry involves in the manufacturing of the turbine blades.

Since the discovery of titanium in 1790 it has been used by numerous industry and application. However it is not purified until the early 1900's. The main reason of it to be purified so late in the century after the discovery is because of the low demand for that type of material. Nonetheless, titanium nowadays has cultivated and earns the trust in industry especially for modern and design application. The titanium have broadly contribute to the field military namely for the aircraft and aviation sector. Due to their unique characteristic that overpower many material such as resistance to corrosion, unique density and relative strength, titanium has found it special place in numerous type of industry. Benefits that are gained from titanium itself have caused the widespread use of it until today.

2.1.1 Characteristics of Titanium Alloy

A handful of these titanium advantages includes widely in their characteristics, properties and processing method. The unique characteristic of the titanium's density as mentioned before are mainly caused by the composition of titanium itself where it consist of 60% steel or nickel base super alloys. This feature in the titanium's properties contribute to the lower weight compared to other metal. When compared to other material such as austenitic or ferritic stainless steel, titanium offers a better tensile strength and can be set by side by side with the lower-strength martensitic stainless steel. Titanium can also be compared to iron base superalloys such as A286 or cobalt base alloys. Titanium may be forged or wrought by standard techniques and it is cast-able, with investment casting as the preferred method. Investment casting also produces a lower cost titanium alloy than the conventional forged/wrought fabricated titanium. It also is formable and readily machine-able, assuming reasonable care is taken.

However, regardless of the excessive utilization and production of titanium, they are high in cost when is set by side with numerous other different metals, due to the difficulty in melting it and problem during extraction and manufacturing process. Nonetheless, the more extended service lives and higher property levels of titanium balance the high production costs. The poor machinability of titanium has encouraged a lot of vast organizations to put a large amount of resources such as money in creating procedures to minimize machining expenses. Thus, cutting tool maker are searching for new instrument materials which could augment device life in the vicinity of such a test.

2.1.2 Applications of Titanium Alloy

Titanium composites are utilized broadly as a part of aviation industry such as aerospace in view of their excellence mix of high specific strength (strength-to-weight ratio), which is retained at hoisted temperature, their excellent resistance to corrosion at high temperature and their fracture resistant characteristics (Ezugwu and Wang, 1997). Some common qualities of aerospace super alloys are austenitic lattice which advances rapid work hardening, reactivity with cutting device materials under atmospheric conditions which has a tendency to build-up-edge and weld onto cutting tools, low heat conductivity which weakens the surface quality and vicinity of abrasive carbide in their microstructures (Che Haron et al., 2001; Ezugwu, 2005).

One of the most frequently utilized titanium combinations is an alpha-beta composite containing 6% Aluminium and 4% Vanadium. This compound, typically alluded to as Ti 6al-4v, displays an amazing mix of corrosion resistance, with high strength and toughness. Common uses incorporate aerospace applications, medical implants, and pressure vessels. On account of restorative applications, stringent client particulars require controlled microstructures and flexibility from melt defects. The interstitial components of iron and oxygen are deliberately controlled to enhance ductility and fracture toughness. Controlled interstitial component levels are assigned as ELI (Extra Low Interstitials).

2.1.3 Machinability of Titanium Alloy

Machining process of titanium alloys is as critical as the cutting of other high-temperature materials. Titanium is machined in the forged condition and regularly oblige to the removal of material up to 90% of the weight of the work piece. The chip will be welded to the cutting tool due to the high-chemical reactivity of titanium alloys, prompting cratering and untimely tool failure. The low thermal conductivity of these materials does not permit the high temperature created in the course of machining to disperse from the cutting tool edge. This result in high tool tip temperatures and disproportionate tool deformity and wear (Klocke et al., 1996).

Titanium alloys maintain quality at high temperatures and display low heat conductivity. This different property does not permit heat produced in the course of machining to disseminate from the tool edge, which results to high tool tip temperatures and enormous plastic deformation wear which causes higher cutting force needed. The high cutting forces and temperatures that may lead to depth-of-cut notching tend to be developed due to the high work hardening tendency of titanium alloys. Moreover, the chip-tool contact zone is generally little, which encourages extensive stress focus because of these higher cutting force and temperatures which leads to premature failure of the cutting tool.

2.2 Turning Operation

Turning machines normally alluded to as lathes, can be found in a diversity of sizes and plans. A manual lathe requires the administrator to control the movement of the cutting tool in the course of the turning operation. Turning machines are additionally ready to be computer controlled, in which case they are alluded to as a computer numerical control (CNC) lathe machine. The common cutting tool utilized as a part of the CNC machine has a replaceable cutting edge (tool insert). CNC machines pivot the work-piece and move the cutting tool established by the commands that are prearranged and precise. In this diverse type of turning machines, the principle parts that empower the work-piece to be turned and the cutting tool to be subjected to the workpiece remains unchanged.

Turning is a kind of material removing process that is utilized to create cylindrical parts. In the course of the turning operation workpiece is put in revolution and the cutting tool will go along the feed direction. The combination between workpiece revolution and device movement will causes diminishing of the workpiece size or width of workpiece. Figure 2.1 shows the fundamental turning operation.

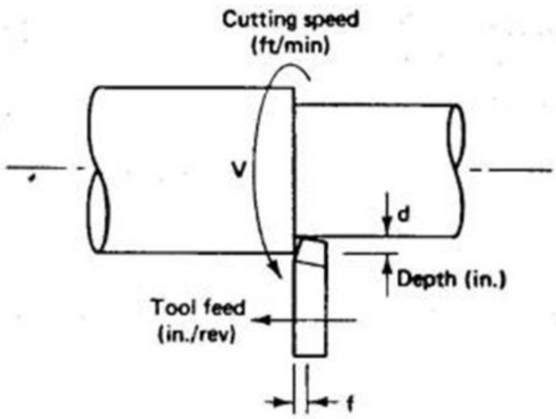

Figure 2.1: Turning operation
(https://rekadayaupaya.wordpress.com/tag/machining-process/)

2.2.1 Hard Turning

According to Gallopi et al., (2006), turning of workpiece with hardness exceeds 45 HRC is often referred as hard turning. Common workpiece materials suitable for hard turning operations involve materials that have undergone heat treatment process such as quenched and tempered case hardened materials. Hard turning basically require high hardness cutting tools with lower feed rate and depth of cut as well as negative rake angle so as to create better execution. Then again, massive nose radius usually 0.8 mm is chosen to accomplish better surface finish (Kumar et al., 2003). The determination of cutting tool for hard turning applications commonly include the use of CBN devices and ceramic since these tool typically have high hardness, durability, and wear resistance making it to be among the possible candidate to perform machining.

Hard turning has the potential for compensating grinding operation and hard turning noteworthy is achieved because of expanded profit and low generation expense can be achieved by it contrasted with grinding. For the most part, the grinding procedure includes low materials removal rate, and depend upon substantial amounts of coolants that affect both the operator's wellbeing and may cause ecological contamination or pollution to the environment. Then again, hard turning offers a few favourable circumstances over grinding, for example, machining time is cut down, high geometry adaptability, and able to get better surface finish quality and friendly to the environment as opposed to the grinding operation (Kumar et al., 2003).

Because of the ever-growing request on hard turning, the completed parts ought to fulfil high quality necessities, for example, dimensional precision and high quality surface finish and hard turning can attain these prerequisites. According to Jiang et al. (2006) found that hard turning utilizing an apparatus with nose radius of 0.8 mm has the capacity to produce parts with surface completion quality equal to mechanical grinding methodology. The surface roughness in hard turning is tantamount to the result retrieved by grinding procedure

2.3 Cutting Parameters

In turning process, the most essential cutting parameters are cutting speed (v), feed rate (f), and depth of cut (d). Cutting speed is the velocity of the workpiece material measured in meters per minute. Feed rate is the rate which the cutting tool is going in millimetres every spindle revolution. Measure of material removed from the workpiece measured in millimetres is referred to as depth of cut. The choice of these parameters impacts cutting strengths, power utilization, and surface finish of the workpiece and the lifespan of cutting tool. Cutting parameters are typically chosen focused around the workpiece, tool material, and tool geometry (Trent and Wright, 2000).

2.3.1 Cutting Speed (v)

As a rule, cutting speed (v) was the essential cutting movement, which relates the velocity of the turning workpiece concerning to the stationary cutting tool. The cutting speed alludes to the edge velocity of the revolving workpiece. It is usually given in unit of surface feet per minute (sfpm) or inches per minute (in. /min), or meters every minute (m/min).