EFFECT OF CUTTING PARAMETER ON SURFACE ROUGHNESS TITANIUM ALLOY (Ti-6Al-4V) WITH DRILLING PROCESS

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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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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Feasibility Study of Drilling Process on Titanium Alloy**

SESI PENGAJIAN: **2014 / 2015 Semester 1**

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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 follow:

………………………………

(Project Supervisor)

ABSTRAK

Titanium Alloy banyak digunakan di industri automotif, industri marin dan bioperubatan. Penggerudian adalah salah satu proses pemesinan yang penting bagi industri aeroangkasa terutamanya dalam kerangka pesawat udara. Manakala, integriti permukaan adalah salah satu parameter yang berkaitan dalam menentukan kualiti permukaan yang dimesin. Oleh itu, dalam hal ini penyelidikan kekasaran permukaan bagi proses penggerudian pada titanium alloy dilakukan. Objektif kajian ini adalah untuk menentukan kesan parameter bagi kekasaran permukaan lubang yang dihasilkan. Kedua, untuk membangunkan satu model matematik menggunakan ANOVA analisis dan akhir sekali untuk mendapatkan parameter penggerudian optimum untuk Ti-6Al-4V. Dua faktor yang digunakan dalam eksperimen ini adalah kelajuan pemotongan 40 m/min dan 60 m/min dan kadar suapan 0.02 mm/rev dan 0.04 mm/rev dan kedalaman pemotongan kekal pada 10mm. Dua reka bentuk faktorial dengan tiga kali replikasi dipilih untuk mengatur parameter pemotongan. Hasil keputusan menunjukkan apabila kelajuan pemotongan dan kadar suapan terendah maka kekasaran permukaan yang terhasil adalah terendah manakala kelajuan pemotongan and kadar suapan tertinggi menghasilkan kekasaran permukaan yang tinggi. Berdasarkan analisis ANOVA, kadar suapan adalah faktor yang paling penting. Model matematik adalah membangunkan dan kesilapan antara eksperimen dan model adalah 15%. Maklum balas optimum diperolehi di memotong kelajuan 40m/min, kadar suapan 0.02 mm/rev dan ini memberi kekasaran permukaan terendah 0.41 µm. Kesilapan pengoptimuman antara eksperimen dan model adalah 13%. Dari kajian ini, walaupun Ti-6AL-4V sukar untuk dimesin namun parameter pemotongan yang sesuai dapat memberikan permukaan kekasaran terendah kualiti permukaan yang lebih baik.

ABSTRACT

Titanium alloys are extensively used in marine application, biomedical, and automotive industries. Drilling is one of the crucial machining process for aerospace industries especially in airframe production. Surface integrity is one of the relevant parameter in determining the quality of the machined surface. Hence, in this research surface roughness for drilling process on titanium alloy are investigated. The objectives of this study are to determine the effect of drilling parameter (cutting speed, feed rate) to the surface roughness of hole produced, to develop a mathematical model using ANOVA analysis and lastly to obtain an optimized drilling parameter for Ti-6Al-4V. Two factors are used this experiment which are cutting speed, and feed rate. The value for cutting speeds are 40 m/min and 60 m/min. In addition, the value for feed rate are 0.02 mm/rev and 0.04 mm/rev. The depth of cut remain constant at 10mm. Two level factorial design with three times replication are selected to arrange the cutting parameter. ANOVA was used to analyse the significant effect of the factors to response. Surface roughness tester are used to measure the surface roughness of the machine surface. The result show that lowest cutting speed, lowest feed rate produces lowest surface roughness while highest cutting speed, highest feed rate produces highest surface roughness. Based on the ANOVA analysis, feed rate is the most significant factor followed by cutting speed. Mathematical model is develop and the error between experimental and model is 15%. The optimum responses are obtained at cutting speed 40m/min, feed rate 0.02 mm/rev and this give out the lowest surface roughness of 0.41 µm. The error of optimization between experimental and model is 13%. From this research, eventhough titanium alloy, Ti-6Al-4V are difficult material to be machined, the suitable cutting parameter are able to give out the lowest surface roughness for better surface quality

DEDICATION

To my beloved parents and siblings

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Praise to Allah for giving me chances as to complete this project and I would like to thank my supervisor Dr Mohd Amri bin Sulaiman for his advice and guidance in completing this project.

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CHAPTER 1

INTRODUCTION

This chapter discusses background of the project, problem statement, objectives, scope and outline of the project.

1.1 Background of the project

Titanium alloys are extensively used in marine application, biomedical, and automotive industries. Titanium alloy are favorable choice in aerospace industries due to the combination of low density (about 50% of the nickel-based alloys), high strength at high temperatures, exceptional resistance towards creep and corrosion resistance properties. Hence, these properties exhibit by titanium alloy are excellent choices for numerous airframe manufacturing and engine components such as fan blades, compressor blade and discs, stator vanes and etc. In addition, aero-engines efficiency is dependent to the static and dynamic masses. Thus by using lightweight materials helps reducing these masses thus resulting in lower fuel consumption and hence the efficiency increases. (M'Saoubi et al., 2008).

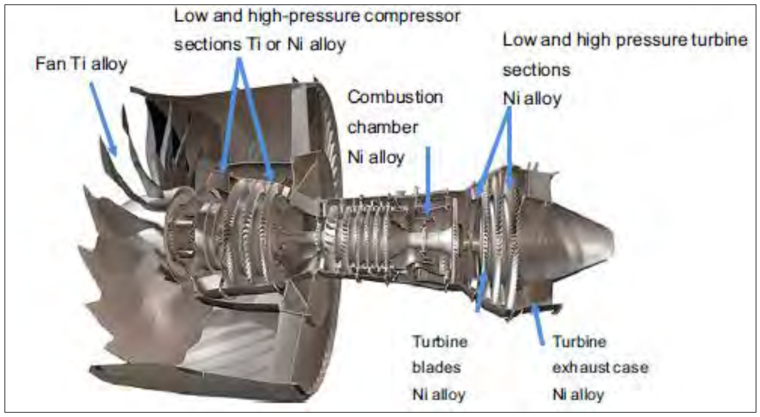


Figure 1.1 : Cross section of jet engine (Ulutan et al., 2011)

Many manufacturing methods such as power metallurgy, isothermal forging and casting has been introduced to reduce the cost for manufactured of titanium components. However, conventional machining are still remains as a popular choice when manufactured titanium parts. Drilling is one of the crucial machining process for aerospace industries especially in airframe production. In addition, drilling mainly involved in the final steps of mechanical components fabrication and it economic impact is significant.

Moreover, it is estimated that 60% of all part the rejection are due to the poor hole quality as the holes are drilled in the finished product, hence poor quality of holes produced results in manufacturing loss. This will eventually increases the manufacturing costs and decresed the production rate (Hocheng 2005). Surface roughness, burr and hole diameter and cylindricity are classified as hole quality. By referring to Zareena et al. (2001), higher surface roughness results in lower capability to resist corrosion, serious wear and catastrophic fatigue hence reducing the performance of titanium alloy.

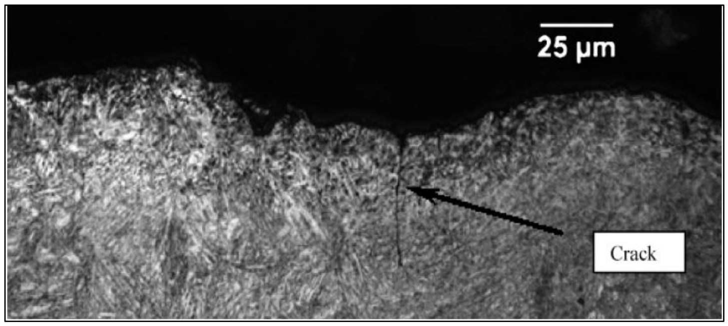
Surface integrity is one of the relevant parameter in determining the quality of the machined surface. Surface integrity are divided into two aspects which are external topography of the machine surface and metallurgy such as microstructure, residual stress, mechanical properties and etc. Surface integrity determines the influence of surface properties and condition of material performance. According to Palanikumar et al. (2006), surface roughness is crucial in determining evaluation of machining accuracy. The are many factors that could contribute to the quality of surface roughness such as cutting tool geometry, cutting parameter, microstructure of the work piece, Built-up Egde (BUE) formation, tool and workpiece vibration and etc. Hence, the ideal surface finish is hard to achieve due to reason stated above (Groover 2007).

Hence, in order to improve hole quality during drilling process of the titanium alloy, it is essential to determine factors, methods, and drill bit during drilling operation. Hole quality depends on the machining conditions such as cutting speed, feed rate, presence of coolant, depth of cut, cutting tool material and etc.

1.2 Problem Statement

In aerospace industry, titanium alloy (Ti-6Al-4V) are favourable and widely used due to its superior properties. In fact, around 40%-60% drilling process are used for material removal processes and this technique is crucial in aerospace industries to produce a hole.

However, despite having superior properties, titanium alloys exhibit high chemical reactivity with almost all cutting tool material resulting the tool material to wear very quickly due to high temperature generated and strong adhesion between tool and workpiece. Titanium alloys are also low in thermal conductivity. Moreover, low modulus of elasticity and its ability to sustain strength at higher temperature further damages its machinability (Che-Haron 2001). Poor surface finish of the machined surface are often produced due to the extensive tool failure and chipping at the cutting edge of cutting tool(Che Haron & Jawaid 2005). The effect of processing parameter also contributes to the damage of surface finish of titanium alloy. Pramanik (2013) stated that surface roughness depend on the cutting condition such as cutting tool material, depth of cut, feed and speed. The hole machining defect will affected the performance of titanium. Higher surface roughness results in lower capability to resist corrosion, serious wear and catastrophic fatigue hence reducing the performance of titanium alloy. (Zareena et al., 2001). Hence this study is important in order to determine the suitable drilling parameter in order to obtain good surface quality.



. Figure 1.2: Fatigue crack on aeroplane (Surface Integrity of Machine Surface, 2010)

1.3 Objectives

The objectives of this study is :

i) To determine the effect of drilling parameter (cutting speed, feed rate) to the surface roughness of hole produced
ii) To develop a mathematical model using ANOVA analysis for surface roughness
iii) To obtain an optimized drilling parameter for Ti-6Al-4V

1.4 Scope of the project

Scope of the project is to perform the drilling operation using CNC vertical milling machine and solid carbide as a cutting tool. Secondly is to analyzing the effect of cutting parameter (cutting speed and feed rate) on surface roughness after the drilling process is done. Next, is to obtain a mathematical model and optimized set of drilling parameter according to ANOVA analysis by using Design Expert Software. All of the findings are depend on the value of surface roughness attain after the drilling process is done.

1.5 Organization

Chapter 1 is the introduction the project which includes background of the project, problem statement, objectives to be achieved and scope.

Chapter 2 is the literature review of this study and projects which consists the introduction the titanium alloy, effects of drill bits on drilling titanium alloy, and influence of process parameter on surface roughness. It reviews about the relevant information to the study.

Chapter 3 is the methodology of this project which contain the approach, methodology and procedure used in this project. All the procedures will be explain and it is consisting of many aspects such as type of machines to be used, selection of drill bits, selection of material to be machined, parameters involved, equipment and method to analyze the surface roughness.

Chapter 4 represent the result and discussion after results is attain from the experiment. This chapter discussed the finding of the obtained result. The analysis of the data is made statistically by using analysis of variance (ANOVA) from Design Expert Software

Chapter 5 is the conclusion of the study. Conclusions are made based on the objectives that are achieves in this study and recommendation is made for further improvement and future work.

CHAPTER 2
LITERATURE REVIEW

This chapter presents related study done by previous research on the surface roughness of titanium alloy in drilling machining. The purpose of this chapter is to gather the information that could contribute to this project. This literature review will focus on the drilling process, cutting tool material, surface integrity, surface roughness, effect of machining parameter on surface roughness. In addition, this chapter also discuss about titanium alloy and its application.

2.1 Drilling Process

According to Tonshoff et al. (1998), drilling process is one the most important metal cutting operation and approximately 30% of the metal cutting operation comprised of drilling process. Drilling is a process which uses multi-point tool for material removal process in order produce a hole and can be carried out by using either conventional or CNC machine. According to Sharif et al. (2012), there are three steps involved in drilling operations. Firstly is centering phase, secondly is the full drilling phase and lastly the break through phase. The first phase is most important in order to prevent the deterioration of the drill from happened and premature wear and torque and thrust force on the tool are constantly increasing in this phase. In addition, once the cutting edges are engaged the full drilling phase occurred and drill point breaks through the underside of the workpiece indicating that the break through phase has begin. The process of drilling is stopped once the drill body passed through the workpiece.

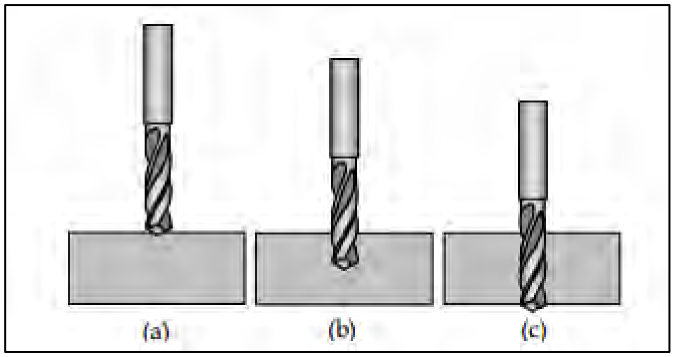


Figure 2.1 : Drilling phases, (a) centering phase (b) full drilling phase (c) break through phase (Machinability of Titanium Alloy, 2006)

Table 2.1 : Recommended parameter for drilling process (Kalpakjian & Schmid 2010)

General Recommendations for Speeds and Feeds in Drilling

		Drill diameter			
		Feed, mm/rev		Speed, rpm	
Workpiece material	Surface speed m/min	1.5 mm	12.5 mm	1.5 mm	12.5 mm
Aluminum alloys	30–120	0.025	0.30	6400–25,000	800–3000
Magnesium alloys	45–120	0.025	0.30	9600–25,000	1100–3000
Copper alloys	15–60	0.025	0.25	3200–12,000	400–1500
Steels	20–30	0.025	0.30	4300–6400	500–800
Stainless steels	10–20	0.025	0.18	2100–4300	250–500
Titanium alloys	6–20	0.010	0.15	1300–4300	150–500
Cast irons	20–60	0.025	0.30	4300–12,000	500–1500
Thermoplastics	30–60	0.025	0.13	6400–12,000	800–1500
Thermosets	20–60	0.025	0.10	4300–12,000	500–1500

2.1.1 Cutting conditions in drilling

Rotational speed of drilling is determined by using the following formula. Let N represent the spindle rev/min

$$\mathbf{N} = \frac{v}{\pi D}$$

where v = cutting speed, mm/min and D=diameter, mm (in).

Feed, f in drilling is specified in mm/rev (in/rev). Recommended feeds are propotional to drill diameter, higher feeds are used with larger diameter drills. Feed can be converted to feed rate into the equation :

$$f_r = Nf$$

There are two types of drilled holes produce in drilling, which are through holes or blind hloes. Through holes can be calculated by using this formula :

$$T_m = \frac{t+A}{f_r}$$

where T_m = machining (drilling) time, min; t = work thickness, mm (in); f_r = feed rate, mm/min (in/min); and A= an approach allowance that accounts for the drill point angle, representing the distance the drill must feed into the work before reaching full diameter. This allowance is given by

$$A = 0.5\, D \tan\left(90 - \frac{\theta}{2}\right)$$

where A = approach allowance, mm(in); and 0 = drill angle.

In blind hole, the depth d is defined as the distance from the work surface to the depth of the full diameter. The equation is given below

$$T_m = \frac{d+A}{f_r}$$

where A = the approach allowance

The rate of material removal in drilling is determined as the product of the drill cross-sectional area and the feed rate

$$R_{MR} = \frac{\pi D^2 f_r}{4}$$

This equation is valid only after the drill reaches full diameter and excludes the initial approach of the drill into the work.