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MICRO-MILLING OF TI-6AL-4V MATERIAL

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Report submitted in partial fulfillment of the requirements

for the award of the degree of

B. Eng (Hons) in Manufacturing Engineering

Faculty of Manufacturing Engineering

UNIVERSITI MALAYSIA PAHANG

June 2016

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LIST OF SYMBOLS

fz	Feed Rate
Ω	Spindle Speed
Ra	Average Surface Roughness
α	Alpha
β	Beta

LIST OF ABBREVIATIONS

Al	Aluminium
C	Carbon
DOC	Depth of Cut
DOE	Design of Experiment
Fe	Iron
H	Hydrogen
HSS	High Speed Steel
N	Nitrogen
O	Oxygen
V	Vanadium
WC	Cemented tungsten

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ABSTRACT

Micro-end milling is one of the promising methods for rapid fabrication of features with 3D complex shapes. However, controlling the micro-end milling process to obtain the desired results is much harder compared to that of macro-end milling due to the size effect and uncontrollable factors. The problem is much pronounced when workpiece material is a difficult-to-process material such as titanium-based alloys which are widely used as material of choice for medical implants. This research is about the effect of machining parameters in terms of feed rate and depth of cut with constant spindle speed in wet and dry condition on Ti-6Al-4V's surface roughness using micro-milling process. This experiment was design using Design of Experiment (DOE) method and few numbers of experiments were constructed. The results show that feed rate is the most critical parameter which effect on surface roughness during machining process followed by depth of cut. Dry condition shows better surface quality compared to wet condition.

ABSTRAK

‘Micro-end milling’ adalah salah satu kaedah yang menjanjikan untuk fabrikasi yang pantas dengan ciri-ciri bentuk 3D yang komplek. Walaubagaimanapun, pengawalan proses ‘micro-end milling’ untuk mendapatkan keputusan yang dikehendaki jauh lebih sukar berbanding dengan ‘macro-end milling’ disebabkan oleh kesan saiz dan faktor-faktor yang tidak terkawal. Masalah ini lebih ketara apabila bahan bahan kerja adalah bahan yang sukar untuk proses seperti aloi berasaskan titanium yang digunakan secara meluas sebagai bahan pilihan untuk implan dalam bidang perubatan. Kajian ini adalah mengenai kesan parameter pemesinan iaitu ‘feed rate’ dan kedalaman permotongan dengan menggunakan kelajuan spindle tang sama dalam keadaan basah dan kering ke atas kekasaran permukaan Ti-6AL-4V menggunakan prosess micro-milling. Eksperimen ini menggunakan kaedah ‘Design of Experiment (DOE)’ dan beberapa percubaan eksperimen telah dihasilkan. Keputusan menunjukkan bahawa ‘feed rate’ adalah parameter yang paling kiritkal ke atas kekasaran permukaan semasa proses diikuti dengan kedalaman pemotongan. Pemesinan dalam keadaan kering menunjukkan kualiti permukaan yang baik berbanding dalam keaadaan basah.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Titanium alloys started getting wide attention in medical field especially as implant material since early 1970s. Its offers features that is comparable to other materials such as nickel. It is particularly suitable for medical usage because of its properties such high strength, wear resistance and compatible with living tissue.

Nowadays, titanium alloys are being the most attractive metallic materials for biomedical applications. In medical field, titanium alloys are used for implant devices replacing failed hard tissue. Examples of implant devices are included artificial hip joints, artificial knee joints, and bone plates. It is also used for dentistry devices such as over dentures, and crowns.

Titanium alloys are classified into three structural types which are based on solid α- and β- solution, alloy based on solid solutions with mixture of chemical compound and based on chemical compound. High temperature and low temperature are the two allotropic modifications which exist in titanium. α- titanium exists at temperature below 882^{o}C and β- titanium at higher temperature up to the melting point(Display et al. 2015).

Surface roughness and burr formation are very important parameters in producing good medical device or part. The proper setting of cutting parameters is very important before the machining process takes place to obtain better surface roughness. This project will be focus on the surface roughness and burr formations during micro-milling process of Titanium alloys by optimizing the parameters during machining operation including depth of cut and feed rate.

1.2 PROBLEM STATEMENT

Titanium alloys in industry are attractive bio-compatible material which are very popular in medical devices and implant due to their high strength-to-weight ratio, wear corrosion, and compatible with living tissue but they are very difficult-to-machine material. Compared to other mechanical micro-machining processes, micro end-milling is the most flexible process to produce micro-scale features among all. It has capability to provide many advantages for manufacturing complex features. However, it is difficult to get good surface finish to the machined part. In micro-machining, the selection of proper parameter is very important. Improper combination of parameters may cause bad surface finish and more burr formation which impose high effect to the manufacturer. Optimization of micro end-milling parameters by finding the correct combination of parameter will increase the quality of machined product.

1.3 OBJECTIVES OF RESEARCH

The objectives of this project are:

1. To study micro-milling characteristic on titanium alloys material.
2. To optimize the cutting parameters in micro-milling Ti-6Al-4V.
3. To observe surface quality of Ti-6Al-4V material when machining in dry and wet condition.

1.4 SCOPE OF RESEARCH

This research will be focus on the surface quality of Ti-6Al-4V during micro-milling process by optimizing the parameters during machining operation including depth of cut and feed rate. The physical micro-milling experiments will be conducted in two conditions which are in wet and dry condition. In order to collect all necessary data, the experiments were design and analyses using Design of Experiment (DOE) method.

CHAPTER 2

LITERATURE REVIEW

2.1 DEFINITION OF IMPLANT

An implant is a medical device used to replace a missing biological structure. It is also used to support a damaged biological structure, or enhance an existing biological structure. Medical implants are man-made devices, in contrast to a transplant, which is a transplanted biomedical tissue. The surface of implants that contact the body might be made of a biomedical material such as titanium, silicone, or apatite depending on what is the most functional. Implant device is usually very complex and small part. It is very difficult to manufacture.

2.2 TITANIUM ALLOYS

2.2.1 Properties of Titanium Alloys

Titanium alloys are classified into three structural types which are based on solid α- and β- solution, alloy based on solid solutions with mixture of chemical compound and based on chemical compound. High temperature and low temperature are the two allotropic modifications which exist in titanium. α- titanium exists at temperature below 882^{o}C and β- titanium at higher temperature up to the melting point(Display et al. 2015).

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