UNIVERSITI TEKNIKAL MALAYSIA MELAKA

NOVEL EDM THREAD WHIRLING TECGHNIQUE FOR ORTHOPEDIC MEDICAL SCREW IMPLANT APPLICATION

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

MUHAMMAD FAQRUL REDUAN BIN ABDUL MAJID

B 050910230

880224-02-5185

FACULTY OF MANUFACTURING ENGINEERING

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Author's Name	:	MUHAMMAD FAQRUL REDUAN BIN ABDUL MAJID
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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)

ABSTRACT

Due to the excellent combination of strength, low modulus and high corrosion resistance. Titanium alloys are increasingly used as biomaterials. Titanium is mainly used in orthopedic injury application, such as bone fracture which required screw fixation. However, the complicated geometrical design and tight tolerance of orthopedic screw limit its fabrication technique. Generally, high strength orthopedic screw were fabricated using single-point threading and thread whirling technique. However, there were few problem encounters by employing these techniques such as rapid tool wear, limited design flexibility, low accuracy and high capital cost. The suitable candidate to overcomes this problems is using electrical discharge machining process in which the material is removed by spark erosion. Since there is no physical contact between tool electrode and workpiece, the tool wear rate is low and the materials hardness is not dependent. In addition, the main advantages of using EDM technique are the accuracy and find surface integrity which is suitable for medical application. However, the selection of EDM as an alternative manufacturing technique for orthopedic screw required a scientific analytical justification of EDM capability compare to current techniques and propose a new EDM method for fabricating orthopedic screw. Three method are proposed and the performance of each method will be evaluated.

ABSTRAK

Kerana gabungan cemerlang kekuatan, modulus yang rendah dan ketahanan kakisan yang tinggi. Aloi Titanium semakin digunakan sebagai bahan perubatan. Titanium digunakan terutamanya dalam aplikasi kecederaan ortopedik, seperti patah tulang yang memerlukan penetapan skru. Walau bagaimanapun, reka bentuk geometri yang rumit dan toleransi ketat skru ortopedik menghadkan teknik fabrikasi itu. Secara umumnya, kekuatan skru ortopedik telah direka menggunakan satu titik bebenang dan teknik berpusing benang. Walau bagaimanapun, terdapat beberapa pernemuan masalah dengan menggunakan teknik-teknik seperti kaedah kakisan pantas, fleksibiliti reka bentuk terhad, ketepatan yang rendah dan kos modal yang tinggi. Kaedah yang sesuai untuk mengatasi masalah ini adalah dengan menggunakan mesin pelepasan elektrik proses di mana bahan yang dikeluarkan oleh hakisan percikan elektrik. Kerana tidak ada hubungan fizikal antara elektrod alat dan bahan kerja, kadar kakisan alat adalah rendah dan kekerasan bahan-bahan yang tidak bergantung. Di samping itu, kelebihan utama menggunakan teknik EDM adalah ketepatan dan mencari integriti permukaan yang sesuai untuk aplikasi perubatan. Walau bagaimanapun, pemilihan EDM sebagai teknik pembuatan alternatif untuk skru ortopedik memerlukan justifikasi analisis saintifik keupayaan EDM berbanding dengan teknik-teknik semasa dan mencadangkan kaedah EDM baru untuk memasang skru ortopedik. Tiga kaedah yang dicadangkan dan prestasi setiap kaedah akan dinilai.

DEDICATION

Especially dedicated to my parent, brothers and sisters

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A special thanks to my supervisor, Dr. Raja Izamshah Bin Raja Abdullah for this supervision in doing this project. I greatly appreciate his consistent encouragement, advice and invaluable guidance throughout the project.

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I would like to express my deepest appreciation and gratitude to my family member for their love, sacrifice, motivation and support in completing this project. Last but not least, I would like to thanks those who have contributed directly or indirectly toward the success of this project.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS & NOMENCLATURE

PSM	-	Projek Sarjana Muda
CNC	-	Computer Numerical Control
EDM	-	Electric Discharge Machine
MRR	-	Material Removal Rate
EWR	-	Electrode Wear Rate
SR	-	Surface Roughness
TWR	-	Tool Wear Rate
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
%	-	Percentages
A	-	Ampere
µs	-	Micro Second
V	-	Voltage
g	-	Gram
mm	-	Milimeter

CHAPTER 1
INTRODUCTION

This chapter is the introductory section of the report. It contains the overview, background, problem statement, objectives, and scope of the study.

1.1 Background of Study

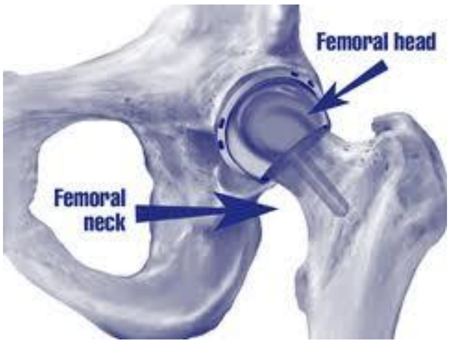
Increasing demand for bone screws, implants and other micro-components creates a need for new techniques that produce specific thread forms quickly and with high tolerances. The hard outer shell and a softer, almost sponge-like core of the human bone requires bone screws to be hard and sharp enough to penetrate the outer shell, without the thread form separating from the soft core (Table 1.1). In addition, the competitive market of bone screw design sees manufacturers change their thread profiles every two to three years, with each profile coming in four different screw designs. A bone screw can be as unique as the human bone it penetrates, and in some cases is designed personally by an orthopaedic surgeon for their patient.

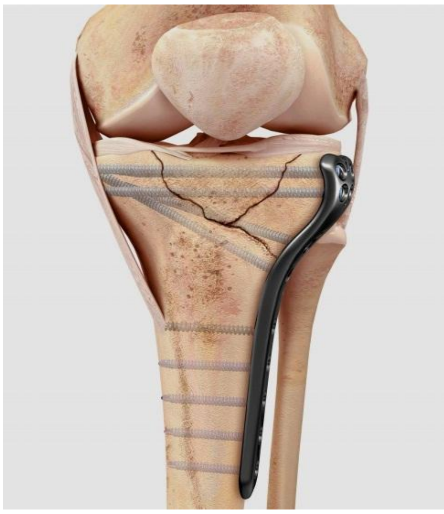
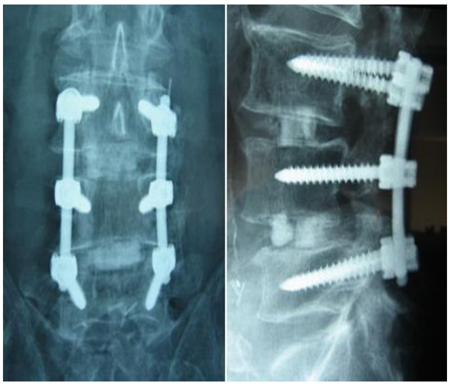
Available in any number of lengths and diameters in standard and custom designs, bone screws tend to have a high aspect ratio, requiring the need for special support devices during manufacture when using the traditional single-point threading tool. Bone screws also have deep threads, requiring many short cuts to be made, which is a slow process that leads to shorter tool life and is worsen when in many cases for medical application the material is from exotic material typically titanium alloys. Another fundamental limitation associated with using a single threading cutter for machining bone screws is the limited helix angle of only seven degrees. Modern screws are designed with helix angles up to 20 degrees. These drawbacks led the medical industry to shift from single-point threading tools to thread-whirling for the production of bone screws.

Thread whirling is a type of thread milling process in which the cutter edges of the tool reside on the inside of the cutter ring rather than the outside. The entire threading operation is performed in a single pass, typically using a thread whirling attachment on a sliding head machine. Other steps in the screw manufacturing process is turning of the front and back of the screw head, drilling of the head, and clearance turning of the hole bottom using the thread whirling attachment. However, since this technique requires a physical contact the tool wear cannot be avoid.

The suitable candidate to overcome this problem is using electrical discharge machining process in which the material is removed by spark erosion. Since there is no physical contact between tool electrode and workpiece, the tool wear rate is low and the material hardness is not dependent. In addition, the main advantages of using EDM technique are the component accuracy and fine surface integrity which is suitable for medical application.

Table 1.1: Application screw on medical part.

No	Implant Device	Application Area
1	Artificial Join : 	Hip : 

2	Knee plate : 	Knee : 
3	Spinal plate : 	Spine : 

1.2 Orthopedic Medical

Orthopedic medical is one of path in medical. Orthopedic is related with bone and joint human body anatomy. Orthopedic pain mostly causes by accident or injury on work, sport and others. Treatment on orthopedic pain taken by doctor is applying the implant device between the fracture bone and orthopedic disease area. Medical device is one of important requirement in orthopedic surgery. The device needs to fulfill the criteria state on medical standard. In the criteria, material selected is important.

1.2.1 Material for Bone Screw.

The material used in medical bone screw called biomaterials. In general material used in medical application, can be categorize into three such as metallic, ceramic and polymeric materials. The material contain in biomaterials must follow the mechanical properties for medical implant called biomechanical properties. The properties are biocompatibility, bioadhesion, biofuctionnality, and corrosion resistance as medical implant relate with human body, human tissues and human sensitivity [1].

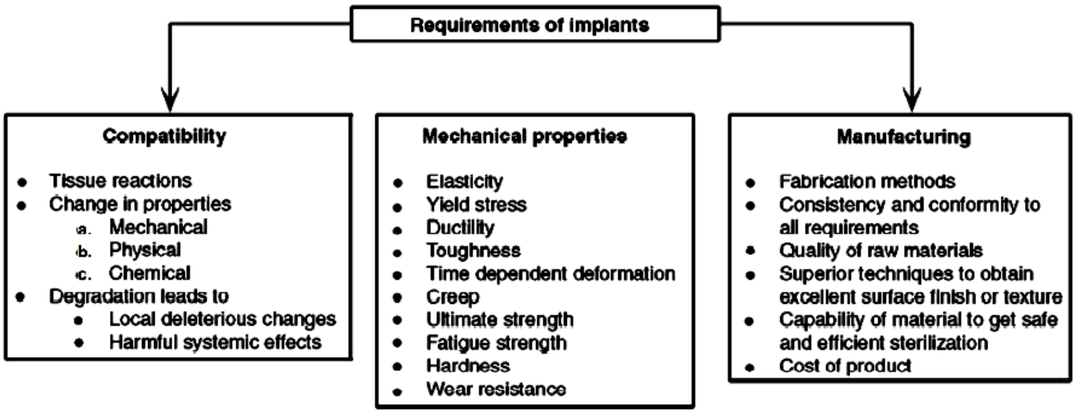


Figure 1.1: Requirement of implants [2].

1.2.1.1 Titanium Alloys

Titanium is one of the material listing in biomaterial group. Titanium is under group metallic biomaterial. Another material in metallic biomaterial is stainless steels, and cobalt alloys. Compare with another two material, titanium alloys is the best material because titanium has good biomechanical properties. Titanium alloys is low in specific gravity and good corrosion resistance. This two biomechanical properties are importance when the patient has more than one implant and the surgery take long time or surgeon operates used the surgical tool for a long time [3].

Table 1.1 show the comparison of three materials in medical application. In this table, titanium alloy is high in strength, high in corrosion resistance, high in biocompatibility and low in stiffness. Titanium also has better tissue tolerance compare with other two materials [1].

Table 1.2: Mechanical characteristics of metal alloys use in medical implant [1].

Characteristics	Stainless steel	Cobalt alloys	Titanium alloys
Stiffness	High	Medium	Low
Strength	Medium	Medium	High
Corrosion Resistance	Low	Medium	High
Biocompatibility	Low	Medium	High

1.2.2 Medical Implant Device from Titanium.

Mostly grade Titanium used in medical is Ti-6Al-4V. The material is combination of 6% Aluminum and 4% Vanadium. This material mostly used because of its harmonizing factor with the human body.

From the listing material in biomaterials group, Titanium Alloys is main material used for device medical implant applied on artificial joint, bone plate, screw, spinal, and other part in human body [1].

Medical grade titanium is used in producing:

a) Pins
b) Bone plates
c) Screws
d) Bars
e) Rods
f) Posts
g) Expandable rib cages
h) Spinal fusion cages
i) Finger and toe replacements

The important part is screw because most part produces from Ti-6Al-4V will attach with screw to apply on disease area.

1.3 Current Methods for Fabricating Titanium Screw

Generally, for typical and high volume screw production, rolling machine is used. However the rolling machine produces parts with high tolerance and low part accuracy which affect the product quality. Which not suitable for medical application.

Figure 1.2: Rolling machine in fabricating screw.

As an alternative to overcome the disadvantages in rolling machine CNC Lathe are used for fabricating screw. However, number of published work [4, 5] reported that the tool wear rate is high when turning the titanium workpiece. Diamond tool is always employed for turning the titanium workpiece which increase the cost because the diamond has the highest hardness and highest heat conductivity among the substances and is excellent in chemical stability [6].

Figure 1.3: Lathe machine fabricating screw.

Another fundamental limitation associated with using a single threading cutter for machining bone screws is the limited helix angle of only seven degrees. Modern screws are designed with helix angles up to 20 degrees. These drawbacks led the medical industry to shift from single-point threading tools to thread-whirling for the production of bone screws. The advantages of single point threading tools has led to the application of thread whirling by using a Swiss machine.

In process to produce Bone screw, the major machine used is Swiss machine. Conventional threading operations on Swiss lathe able in multiple threading cuts by using a single point tool. This machine is the better machine in produce long screws. As shown in figure 1.2, Swiss lathe used with whirling cutter. Whirling cutter rotates at a high speed while bar stock rotates at a low speed. Whirling cutter improve quality and productivity.

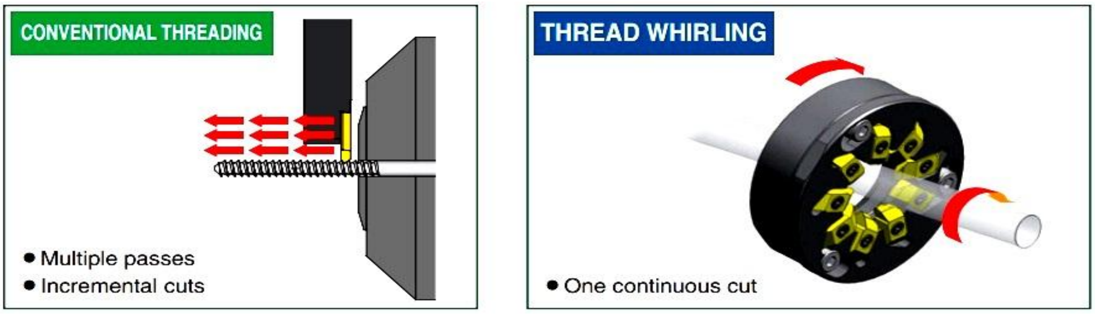


Figure 1.4: Swiss lathe. comparison between conventional thread and thread whirling.

The machine also a fast method, due to using six inserts in the milling cutter and ideal for difficult materials while eliminating chip problem. The process using a Swiss machine is very expensive.

The current machining has the problem especially in tool wear and tool life. Current machining is Swiss lathe is a physical contact concept apply to the machine. That means the tool bits will touch the work piece to doing shaping process. The tool will wear after touch the work piece and shape the work piece. Hard material will make faster tool wear happen. Since the material used in producing bone screw, the material is titanium alloy whereas the hard material.

The study will propose a new method in producing bone screw. The new method is producing bone screw using Electric Discharge Machine (EDM) Die Sinking. This new method or suggest base of the problem happen on the previous machining like a tool ware, and expensive production cost. The non-physical contact on EDM will used for solution on tool ware and EDM machining not too expensive. The new method also for the problem of current process in machining hard material.

The suitable candidate to overcome this problem is using electrical discharge machining process in which the material is removed by spark erosion. Since there is no physical contact between tool electrode and workpiece, the tool wear rate is low and the material hardness is not dependent. In addition, the main advantages of using EDM technique are the component accuracy and fine surface integrity which is suitable for medical application.

Table 1.3: Comparison capability of machine in fabricating titanium material.

	Rolling	**CNC Lathe**	**Swiss**	**EDM**
Tool Wear	High	High	Medium	Low
Accuracy	Low	Medium	High	High
Time	Medium	Medium	High	Low
Cost	Low	High	High	Low
Shape Hard Material	Low	Medium	High	High

Table 1.4: Number of the capabilities of fabricating titanium material [/].

	Rolling	**CNC Lathe**	**Swiss**	**EDM**
Tool Wear	X	X	X	/
Accuracy	X	X	/	/
Time	X	X	/	X
Cost	X	X	X	/
Shape Hard Material	X	X	/	/
Total [/]	**0**	**0**	**3**	**4**

1.4 Objectives

Both the difficulties and disadvantages for fabricating Titanium Screw were causing to initiate this project.

a) To design a new concept for fabricating electrode using EDM Sinker on producing bone screw.
   - The study was conducted to solve the problem in current machining used for fabricating bone screw.

b) To provide an alternative process for screw thread fabrication method.
   - The study was conducted based on the suggested method for producing the electrode used for EDM Die Sinking to machining the titanium alloy.

c) To identify the capability of EDM Die sinking in produces the screw.
   - The comparison was made based on a screw produce by the current machine and the screw produce by using EDM Die Sinking.

1.5 Scope of Project

The scope of the research was limited on the EDM Die Sinking on the produce the screw used for orthopedic medical implant. The research will fine the capability of EDM Die Sinking in make it screw and follow the specification state on the standard or tool and equipment manufacture in medical implant.