UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MODELLING EFFECT OF CUTTING SPEED AND FEED RATE IN BONE DRILLING

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

by

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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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 (Type your department's name here) (Hons.). The member of the supervisory is as follow:

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↑ *3 cm*

ABSTRAK

Penggerudian minimal tulang mempunyai permintaan yang besar dalam proses pembedahan ortopedik kerana ia membantu dalam penetapan yang lebih baik dan cepat penyembuhan tulang rosak. Tujuan kajian ini adalah untuk mengetahui susunan optimal daripada tulang penggerudian parameter yang memotong laju dan makanan kadar untuk tenaga dan suhu minimum semasa penggerudian tulang menggunakan simulasi berubah bentuk 3D. Eksperimen penggerudian tulang telah dijalankan menggunakan teknik faktorial lengkap dan berdasarkan keputusan yang diperolehi model 3D permukaan sambutan dibangunkan. Model ini telah digunakan sebagai fungsi objektif dalam mengubah bentuk 3D perisian. Sebelum model pelbagai pemotongan kelajuan dan kadar suapan, model pengesahan telah dibuat melalui eksperimen dengan tulang lembu kortikal dan 420B keluli tahan karat sebagai alat. Nilai tenaga dan suhu yang diperolehi daripada simulasi dalam pemodelan telah disahkan dengan data uji kaji. Satu eksperimen dalam penggerudian tulang telah dijalankan menggunakan mesin gerudi CNC dengan dinamometer untuk mengukur daya dan Inframerah Termografi untuk mengukur suhu. Keputusan eksperimen menunjukkan pengesahan bahawa berubah bentuk 3D Berjaya berkesan boleh meramalkan suasana optimum memotong kelajuan dan makanan kadar daya dan suhu yang dicapai dalam proses penggerudian tulang. Parameter memotong mencadangkan 600 rpm dan 25 mm / min kelajuan pemotongan dan makanan pada kadar yang terbaik untuk pakar bedah ortopedik untuk mengurangkan penggerudian disebabkan kecederaan tisu tulang.

ABSTRACT

Minimally invasive drilling of the bone has a great demand in the orthopaedic surgical process as it helps in better fixation and quick healing of the damaged bones. The aim of the present study is to find out the optimal setting of the bone drilling parameter which are cutting speed and feed rate for minimum force and temperature during the bone drilling using simulated Deform 3D. The bone drilling experiments were carried out using the Full Factorial technique and based on the result obtained a response surface 3D model was developed. This model was used as an objective function in Deform 3D software approache. Before modelling the various of cutting speed and feed rate, modelling validation was made through experiments with cortical bovine bone and 420 B stainless steel as a tool. The values of force and temperature obtained from the simulation in modelling were validated with an experimental data. An experiments in bone drilling was conducted using CNC drilling machine with dynamometer to measure the force and Infrared Thermography to measure the temperature. The result of confirmation experiments showed that the Deform 3D sucessfully can effectively predicted the optimum setting of cutting speed and feed rate to achieved force and temperature during bone drilling process. The suggested cutting parameter of 600 rpm and 25 mm/min is the best cutting speed and feed rate for orthopaedic surgeons to minimize the drilling induced bone tissue injury.

DEDICATION

To my beloved parents, who always encourage and give all support that I really need during accomplish this thesis

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ANOVA	-	Analysis of Variance
AMG	-	Automatic Mesh Generation
AISI	-	American Iron and Steel Institute
BV	-	Body Volume
BMD	-	Bone Mass Density
C	-	Celcius
CNC	-	Computer Numerical Control
D	-	Diameter
DOE	-	Design of Experiment
DEFORM	-	Design For Forming
DF	-	D egree of Freedom
FEA	-	Finite Element Analysis
F	-	F Test (ANOVA)
FE	-	Finite Element
FEM	-	Finite Element Modelling
GPA	-	Gigapascal
MPA	-	Megapascal
MM/MIN	-	Millimetre per Minutes
N	-	Newton
ON	-	Osteonecrosis
SEM	-	Scanning Electron Microscopy
RSM	-	Respond Surface Methodology
RPM	-	Revolution per Minutes
TV	-	Tissue Volume
ρ	-	Density
G_{cs}	-	Toughness
K_{IC}	-	Fracture Toughness

σys	-	Compressive strength
σyt	-	Tensile yield strength
μ	-	Mean average friction coefficient
3D	-	3 Dimensional

CHAPTER 1
INTRODUCTION

1.1 Research Background

In orthopaedic surgery, bone drilling is a mainly element of an internal fixation in the cause of fracture in human bone and in this field, it is an important process to conduct the testing before insertion of screws into the bone. Besides that, with the evolution of modern surgery, bone drilling becomes a common step of an every procedure in orthopaedics. During the operation, it may produce the frictional force and heat generated around the drill hole bits. Then, the heat generated will cause thermal necrosis. When rising up the force needed for penetration to the bone, it will produce a poor control of the drill.

In respect to current fracture fixation principles or reconstructive surgery, every loosening of implants in bone is an adverse side effect. The implant failure rate for lower leg osteosynthesis is 2–7% (Augustin et al., 2007) and is higher compared to upper extremity due to physiological stress during locomotion that causes the damage of bone structure and many parameters influence loosening of bone implant interface. One of them is thermal osteonecrosis and it also effects of frictional heat generation during orthopedic operation that can reduced the vitality of the bone.

According to Erikson *et al*,. (1986) various parameters have been studied to reduce heat generation during bone drilling, including variations in drill design, drilling parameters and coolant delivery. Many factors contribute to heat generation during drilling but many researched focused only on a single or only several parameters of this rather complicated issue. The ideal method for determining the bone temperature during drilling is difficult to define because bone is a complex anisotropic biological tissue, with organic and inorganic components. Besides that bone temperature must be below the temperature of 47 °C during drilling to avoid thermal osteonecrosis..

According Bertollo *et al*,. (2010) with the development of mechanical engineering technologies in the study of the drilling parameters and the dependence of the axial drilling force in bone drilling, shows that temperature is an important factor to contribute the damaged to the composition inner bone. In addition, many geometrical and operational variables influence both the performance and maximal temperature elevation in bone as result of the use of drill bits. Performance and maximal heat generation associated with a particular drill-bit are inevitably interrelated. As has been outlined above, prominent geometric variables include point angle, rake angle, diameter, chisel edge length and flute number. The maximal temperature attained during drilling and the performance of a drill-bit is highly dependent on the specific drill design. Then, it is significant to realize the of bone drilling conditions and material behaviour on the bone drilling. Several researchers in the biomechanics find solutions to optimize the bone drilling performance based on the parameters such as feed rate and cutting speed. Optimization of cutting parameters is important to evaluate the thermally induced damage to the bone which will enhance screw interracial strength or bone-implant. Besides that, to want the operation successfully a finite element modelling (FEM) of bone cutting could be an important extension too, and possible substitute for experimental work as it eliminates equipment costs and as well as increasing potential health without burden the patients with real situations. By using the modelling bone drilling using FEA can give benefit for validation and the best optimum value of cutting parameters. Then, it also can be believed of a reliable tool for the development of new surgical technique for the future.

However, the type of material or compositions in the bone is the primary problem when the drilling processes occur because the structure of bone is complex. So, when the existence of the Finite Element Analysis (FEA) in modelling in the orthopaedic field, it can overcome the problem among the patients because can predicted the values of force and temperature during the drilling process. The process can be modelled by using the Finite Element Analysis (Deform 3d) and from this simulation results many surgeons can known the optimization any value of cutting parameters that want to know . Analysis model that can be applies to the tools during stress analysis in bone drilling. The finite element software use is Deform 3D is the best software for forming process which is can give a good simulation and prediction of drilling temperature , force and others. This simulation can give a significant appearance on process behaviour during a simulation occur. The drill bits made up of 420 B stainless steel act as a tool which gives penetration through the bone surface. The bone drilling process and formation of chips can see in the figure 1.1.

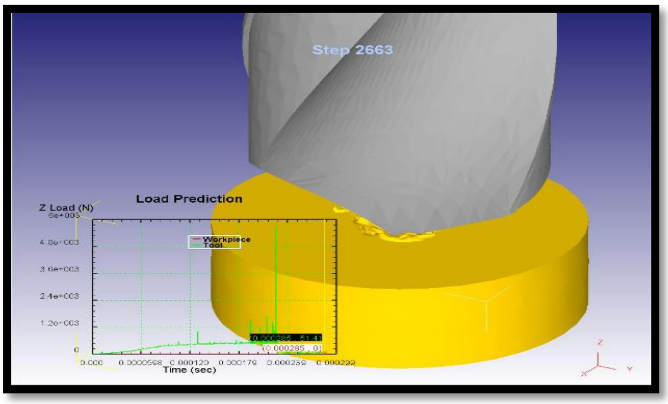

Figure1.1: Formation of chips develops in FE model

In this project, how to learn the common effective parameters include cutting speed and feed rate that are influenced to reducing the force and temperature in the bone drilling operation. Besides that, by utilizing off the base parameters may well cause bone tissue damages during bone implantation and increasing thermal injury in respect to compare with heat generation. In this research project, all the outcomes of the previous studies were identified from a comprehensive by collecting literature review and a series of experiments and numerical simulations were conducted to analyse the structural and thermal processes involved in modelling the effects of feed rate and speed using Finite element analysis (FEA).

This FEA considered as a promising and reliable technique for the development of new surgical procedures in the near future. FEA method has been used to study the several variable that influenced many outcomes likes force and temperature of the bone levels under various different conditions, but it is not yet an adequately applied to model bone cutting. In fact, finite element analysis studies describing thermo-mechanics of bone cutting. So, in this project, the FEA software used to simulate the behaviour when the drilling process occurs is called Deform -3D software.

1.2 Problem Statement

Many problems rise up when bone drilling in orthopaedic surgery operation, which are the high speed surgical drills means that involved the high cutting speed and feed rate that give effect to the force & temperature in the bone (Allan et al., 2005), blunts drill, which means using the old drill bit.

Besides that, by not controlling the cutting parameter may cause the problem of hole accuracy of the bone, which means that the penetration of drill bit to the bone is not accurate. In addition, when the screw insert into the fracture bones, thermal injury occur in the bone because the friction between the drill bit and the bone during the process . It will generate more heat and will be effect the hole in the bone which are may produced the burr during the drilling operation. Then, the problem is how to control the temperature, which to reduce heat generation in the bone and other unpredictable problem will be occur during the bone drilling operation (Izamshah *et* *al,*. 2014). Besides that, the desired outcome of bone drilling is always to produce an accurate hole on bone to prevent the tissue damage, no thermal injury and mechanical distortion on the bone tissue. Besides that, the ‗old drill bit' which functions to remove from a small fragment set chosen at random operating and this blunts bit produce more thermal damage that will get the thermal necrosis. Thermal injury occurs in the bone because the friction between the drill bit and the bone during the drilling process that will generate more heat (Augustin et al., 2007).

In addition, by not controlling the parameter such as forces during the process it also give effect to the bone structure. An increase forces during the penetration of drill bit to the bone surfaces which can cause drill wear. Drill wear can causes a rises of temperature and causes bone tissues damaged. Besides that, it will effect the hole in the bone, which are producing more burr at the structure of the bone. It also can reduce the stability and strength of the fixation. The increased force may also result in broken drill bits and possible injury to the surgeon from the sharp ends of heat generation which the thermal insult to living tissue causes damage and eventual cell death. It has been shown that heating above 50°C causes irreversible changes to the physical properties of bone and probably changes in the collagen of the matrix. Heat generation is always concerned with the design of the drill in order to prevent thermal osteonecrosis whereas the bone temperature must always below the temperature of 50°C during the bone drilling process. Besides that, the drill bit must should be always in maintenance to prevent side effect to the patient. Hence, the desired outcome of bone drilling is always to produce low temperature and force effects on the bone tissue. In this project, by using a finite element Analysis (FEA) which can give a good simulation and prediction values of temperature and force during the cutting process before the real situation occur.

1.3 Objectives

The objectives of this project are:

1. Model the effects of drilling parameter (cutting speed and feed rate) on bone drilling performances (temperature and force).
2. Optimize the drilling parameter (cutting speed and feed rate) for the effectively in the bone drilling process in order to get minimum force and temperature.
3. Validate the effectiveness of the proposed optimize value

1.4 Scope of the Project

This project focuses on the Finite Element Analysis (FEA) modelling of machining simulation is the main shoulder to gain an important significance in the biomechanical research of the bone drilling process. A common tool in numerical simulation is the finite element Analysis (FEA), which can be applied in various ways, such as in structural mechanics and thermodynamics. A drill bit that made up from 420 B stainless steel material and elastic plastic material of bone will design and modelling by using Deform-3D stimulation. The stimulation is actually based on real situation or model and the result must be validated by experiments. After that, the effect of force and temperature is predicted by Finite Element Analysis (FEA). This project only focuses on how feed rate and cutting speed can give outcomes to the reduces the force and temperature by seeing the expected result during the stimulation. The result in FEA will be validated with many trials. Next, a set of database from the stimulation will be generated from the presence file in the Deform-3D and to maintain better resolution in the values of force and temperature which a different mesh generation scheme is used.