Thermal Analysis of Bovine Bone Drilling

by

Muhammad Zamil bin Abdullah

Dissertation submitted in partial fulfillment of the requirements for the

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Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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Approved by,

(Dr. Hasan Fawad)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD ZAMIL BIN ABDULLAH

ABSTRACT

In medical practices, high speed surgical drills are usually used when drilling the screws into the fracture bones. The friction between the drill bit and the bone during the drilling process will generate heat. This heat then will produce the thermal necrosis into the bone. Parameters involve in heat generation are spindle speed, drill bit diameter, drill bit point angle, feed rate, and the bone's properties. The focus will be on the setup of the experiment test rig to perform the bovine bone drilling and the thermal analysis of this experiment using ANSYS. The principles of heat transfer mechanism and complex thermo-mechanical equation from the machining theory will be used alongside anisotropic properties of the bone. This project will look into the problem of high heat generation during drilling process and the process parameters that will control the drilling temperature. Drilling tests were performed on mild steel cylinder bar and bovine bone femur. The effect of spindle speed and feed rate on the temperature was explored. The temperature during drilling is linearly increases with the depth of the specimen.

ACKNOWLEDGEMENTS

Author wishes to acknowledge Dr. Hasan Fawad for his useful advice and helpful discussion, Munaibah binti Mohd Mokhtar for providing me with the thermal result of numerically valid thermal model data, and also Mohd Hafiz bin Safian for his support with the drilling experiments. This project was supported by Universiti Teknologi PETRONAS through Final Year Project.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Drilling is one of many parts in healing the fracture bone. The rise of the temperature during bone drilling is a main parameter to the bone necrosis. A main concern when drilling the bone is the thermal damage to the bone. The power that usually use in drilling is electrical power. The temperature rise during bone drilling is proportional to the drilling speed. The bone is very sensitive and can be damaged by heat generated during drilling process. If the temperature during drilling increases above 55^0C for a period more than 30 seconds, it will cause a great damage to the bone. Drilling is good for the healing of the bone but the heat generated may cause bone necrosis. This project will look into the problem of bone necrosis and try to control the drilling process parameters that will minimize the heat generation. The main focus of this project will be the thermal analysis of bovine bone drilling and the setup of experimental test rig to perform the drilling.

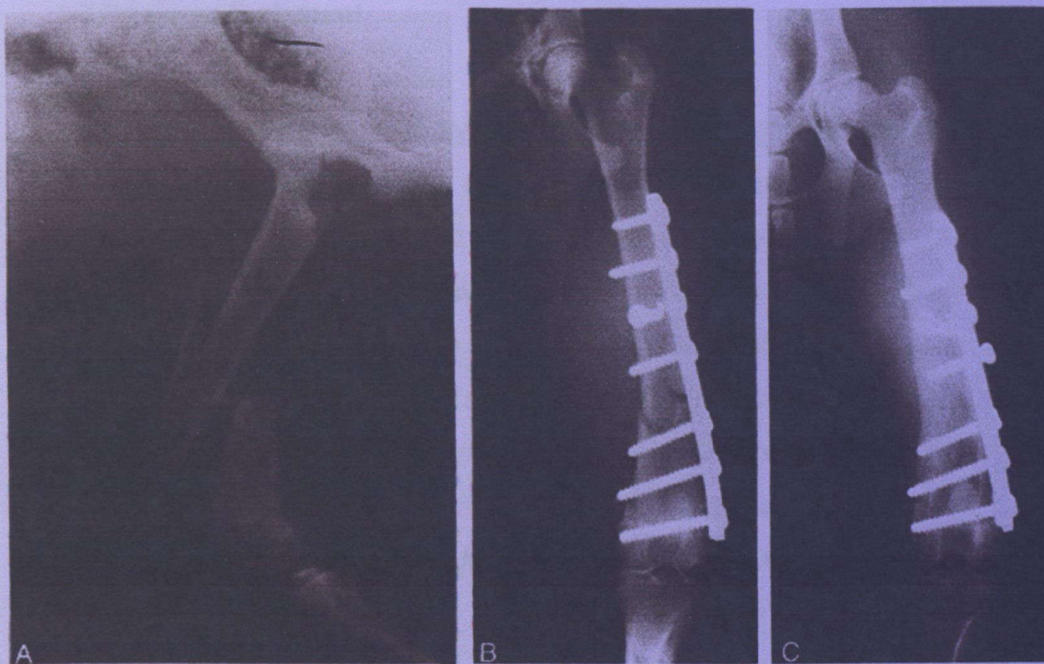

FIG. 29-12 (*A*) Lateral radiograph demonstrates a comminuted diaphyseal femoral fracture in a 7-month-old dog. (*B*) Cranial–caudal radiograph demonstrates the fracture following reduction and fixation using a bone plate and screws. (*C*) Radiograph 5 months following fixation.

Figure 1.1.1: X-ray Images of Bone, Screws, and Plate

1.2 Problem Statement

Bone fracture can cause by any accident that happen. Accident can happen anytime, anywhere even when sleep on the bed. The medical field usually uses screw or plate for support the fractured bone in time to heal the bone. This process involves drilling to put the screw or the plate through the bone. Heat generated during the drilling is basically from the product of shearing. Shearing of the bone's surface started as the drill bits touch the bone. This shearing process would break the intermolecular bonds in the bone. Intermolecular bond is a force that attracts and holds the molecules together. Breaking these bonds would release energy and then this energy will turn to the heat. Friction between the drill bit and the bone also is a factor that affects the drilling temperature. Friction is a resisting force of the relative motion on the solid surfaces. Heat effect of drilling is more severe compare to shearing. It is because the drill bit is embedded in the bone and making heat generate to a small area. When the drill bit is moving into the bone, the temperature of the heat generated will keep increase until it reaches its steady state. So the temperature is linearly increases with the depth of the bone.

1.3 Objective

The objectives of this project are:

1. To setup a laboratory scale test rig to measure temperature during drilling of the bone and the drill tip.
2. To analyze the thermal effects of bovine bone drilling using ANSYS software.
3. To validate the numerical heat transfer model with the result of bovine bone drilling experiment.

The experiment, analysis, and the numerical model will be done based on the literature research and the experimental results.

1.4 Scope of Study

The scope of this project is doing research on bovine bone drilling, heat transfer analysis, designing bone drilling test rig model, performing experiment using test rig and thermal analysis of the data acquired using ANSYS software. The research is important for better understanding of how bone necrosis happen when drilling and what parameters that affect the temperature. The outcome of this project will benefit the medical specialist in order to gain more skills in healing the bone fracture.

1.5 The Relevancy of the Project

In term of industry, this project would enhance medical field, especially in the orthopaedic sector. The simulation of this project would help doctors in their works, thus maintaining the consistency of their knowledge and skills. The simulations would provide the information on how to control the parameters of bone drilling, while the validation would increase the confident in the usage of the modelling simulations. While for the community, this project would benefit people by lowering the probability for human to have thermal bone necrosis. Accidents that may cause bone fracture can happened every day, so by having the up to date controlling parameter would minimize the defect occur in the bone and these will benefit all level of society.

CHAPTER 2

LITERATURE REVIEW

2.1 Thermal Necrosis Threshold

Udiljak, Ciglar, and Skoric (2007) say that in order to reduce the drilling temperature, the treatment needs to be performed as quickly as possible so that the heat does not penetrate the bone [1]. This literature shows that the drilling speed can control the heat generation. This can achieved by increase the drill axial speed. But the excessive of the drill speed can cause further fracture of the bone. When the value of the feed rate per tooth increases, the axial drilling force also increases, but at the same time, its increase reduces greatly the time of machining [1]. This means that the shorter time of the friction between the drill bit and the bone will reduces the amount of the heat generated. So this recommends us to use right value of the feed rate per tooth. The drill tip angle in the bone drilling process has a very high influence on the axial force [1]. Smaller drill tip angle can decreases the axial force but this reduction does not affect the drilling temperature. But it is better to use smaller drill tip angle when bone drilling.

Natali, Ingle, and Dowell say that blunt drill bits will generate higher temperatures and even smoke, while the increased force required for penetration causes poor control of the drill, uncontrolled bursting through the cortex or drill breakage [2]. This can shows that the increased force to increase the drilling speed can cause the drilling process become out of control. So it is very important to not use excessive speed so that the drill bit will not break. There is a correct angle at which a blade should be applied when cutting: sharpening a pencil with a knife is possible only with the appropriate angle of the blade, and a sharp edge [2]. Therefore the appropriate angle of the blade and a sharp edge should also be applied when drilling the bone. These two principles require knowledge of the material being drilled in order to suit this to the characteristic of the drill bit. Thermal insult to living tissue causes damage and eventual cell death [2]. This means the increased of temperature during drilling can cause damage to the bone structure and the death of the cell of the bone.

Augustin, Davila, Mihoci, Udiljak, Vedrina, and Antabak (2007) say that during the drilling of the bone, the temperature could increase above 47 ^{o}C and cause irreversible osteonecrosis [3]. If the temperature increases above 47 ^{o}C, serious damage will occur to the bone. The fracture also may even take longer time than usual to fully recover. During drilling, the resistance of compact cortical bone causes increase of bone temperature [3]. This means that the frictional heat cause the bone temperature to increase and result in thermal bone necrosis. The problem in this project is to determine the specific thermal damage to the bone. According to Augustin, Davila, Mihoci, Udiljak, Vedrina, and Antabak (2007), "many parameters have influence on the increase in bone temperature during drilling. External irrigation is the single, most important factor in decreasing the increase in bone temperature during drilling and must be used for bone drilling. Simply put, the optimal method for decreasing the increase in bone temperature during drilling is: use smaller drill diameters with lower drill speed and higher feed-rates" [3].

2.2 Process Parameter by Heat Modeling

The relationship between drill geometry, drilling recommendations, and bone properties pose a challenge in determining optimal set of bone drilling parameters to minimize the temperature. Few attempts have been made to develop a thermal model for the bone drilling process. Davison and James (2003) developed thermo-mechanical equation from the machining theory to predict heat transfer during drilling [4]. The model was coupled with a heat transfer finite element simulations to predict the temperature. Tu et. al. (2008) presented a model to simulate the rise of the temperature during bone drilling using ABAQUS software to estimate the bone and drill-bit temperatures [5]. Lee et. al. (2011) presented a new thermal model for bone drilling which combines a heat-balance equation for the system of the drill bit and the chip stream by using a heat diffusion equation for the bone, and heat generation at the drill tip coming from the cutting process and the friction [6]. The model was solved numerically using a tailor-made finite-difference scheme for the drill bit-chip stream system, coupled with a classic finite-difference method for the bone.

2.3 Influencing Parameters in Bone Drilling

This project is basically looking into the medical practice problem, so it is very important to have the drill geometrically model consistent to the medical practice. The project bovine bone drilling experiment will includes the spindle speed, feed rate, drill bit diameter, and the point angle. Table below will show the parameters' value needed for the experiment.

Table 2.3.1: Bone Drilling Parameters

Parameter	Range	Literature
Spindle Speed (rpm)	400 to 3000	[3, 7, and 8]
Feed Rate (mm/s)	0.42 to 3.3	[7 – 9]
Drill Bit Diameter (mm)	1.5 and 4.5	Orthopedic-surgery practice
Point Angle (deg)	70 to 130	[3 and 9]
Drilling Depth (mm)	9	Common thickness of the cortical portion of bone, especially for bovine femur or tibia.

These parameters will be used in bovine bone drilling experiment.

2.4 Temperature Measurement Method

Past researchers have developed various techniques to assess temperatures during high-speed cutting processes such as drilling. Some of these techniques are bone-embedded thermocouples, tool-embedded thermocouples, and infrared photography. Bone-embedded thermocouples were done by embedding it to the bone, drilling temperatures were measured in human and bovine cortical bone by placing a thermocouple inside a 3.2 mm diameter drill bit close to its cutting edge [9]. Bachus et. al. (2000), Krause et. al. (1982), and Abouzgia and James (1997) used this thermocouple embedded bone method [7, 10, and 11]. Inconsistent results have been achieved using these methods. Because of the poor thermal conductivity of the bone, inconsistent structure, and the difficulty in modeling for heat-transfer purposes, embedding thermocouples in the bone adjacent to the drilling operation is not a very suitable method of measuring the temperatures. A K-type thermocouple was bedded inside the drill and its leads were then glued along the drill barrel was introduced [12]. Another research of temperature in drilling of bovine mandebular bone was conducted using Thermovision 900 system [13]. Thermal pictures were recorded surrounding the drilling areas. Infra-red pyrometer has been used as a remote sensor to measure the temperature at the tool-chip interface in high-speed milling operation where the thermal camera was focused on the freshly milled surface behind the end mill [14].

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This project will be conducted according to this methodology to meet the objective. Firstly is to understand the objective of this project and do literature survey on present numerical models for bone drilling being used, the experiment test rigs that are being used for temperature and other parameters measurement, detail equipments for experimental setup, detail material model for bones, and the models used to simulate the heat drilling as heat source. Secondly, procurement of equipments or accessories and bovine bone sample. Thirdly, construct the experiment test rig with calibration and initial testing. Fourthly, do modeling and simulation of the drilling process using ANSYS software. Fifthly, evaluate the results by analyzing the simulation and performing the experimental results. Then the comparison of both results will also be analyzed. Sixth and lastly, the validated numerical model for animal bone will be extended to be used for human bone. After that evaluation will be analyze from the experimental model and the numerical model. Figure 3.2.1 simplifies the flow of the project methodology.

3.2 Project Activities

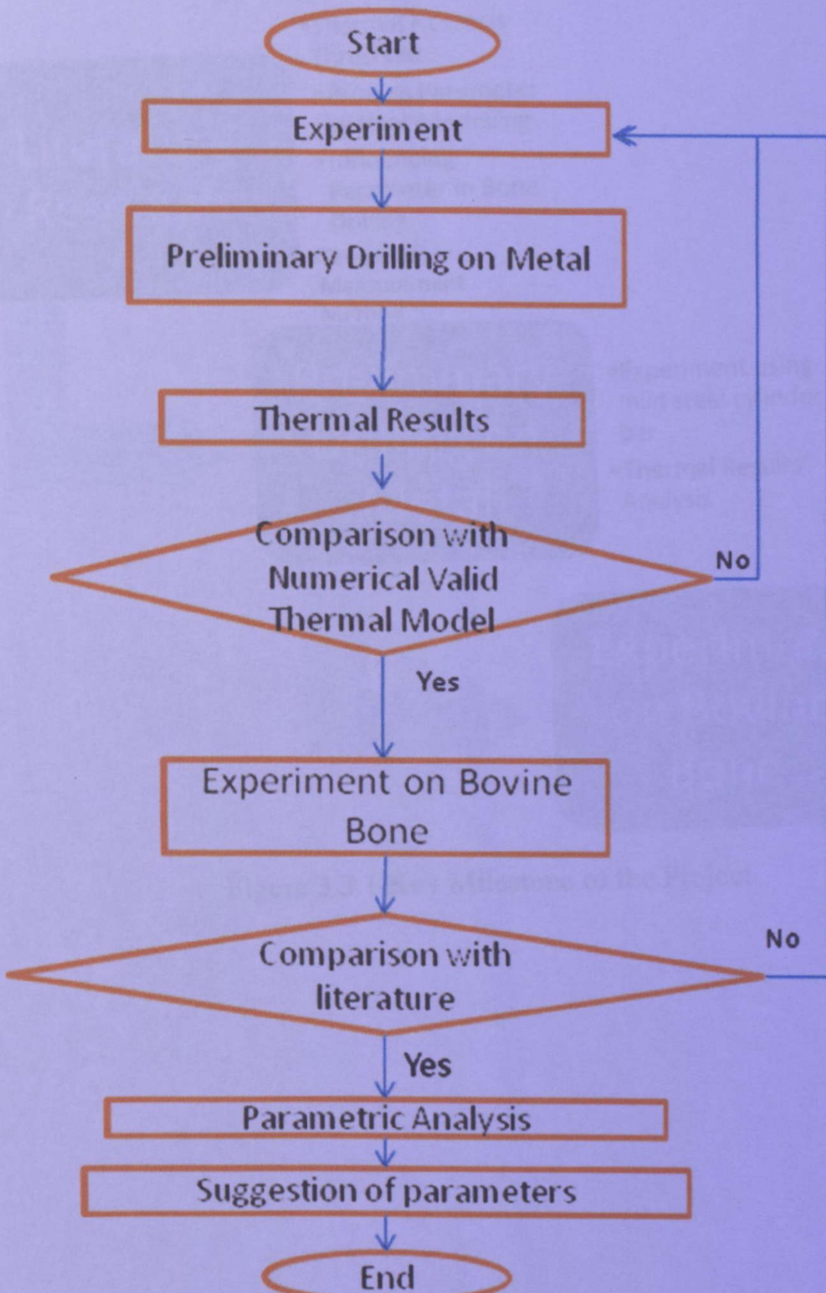

Figure 3.2.1: Process Flow Chart of the Project

3.3 Key Milestone

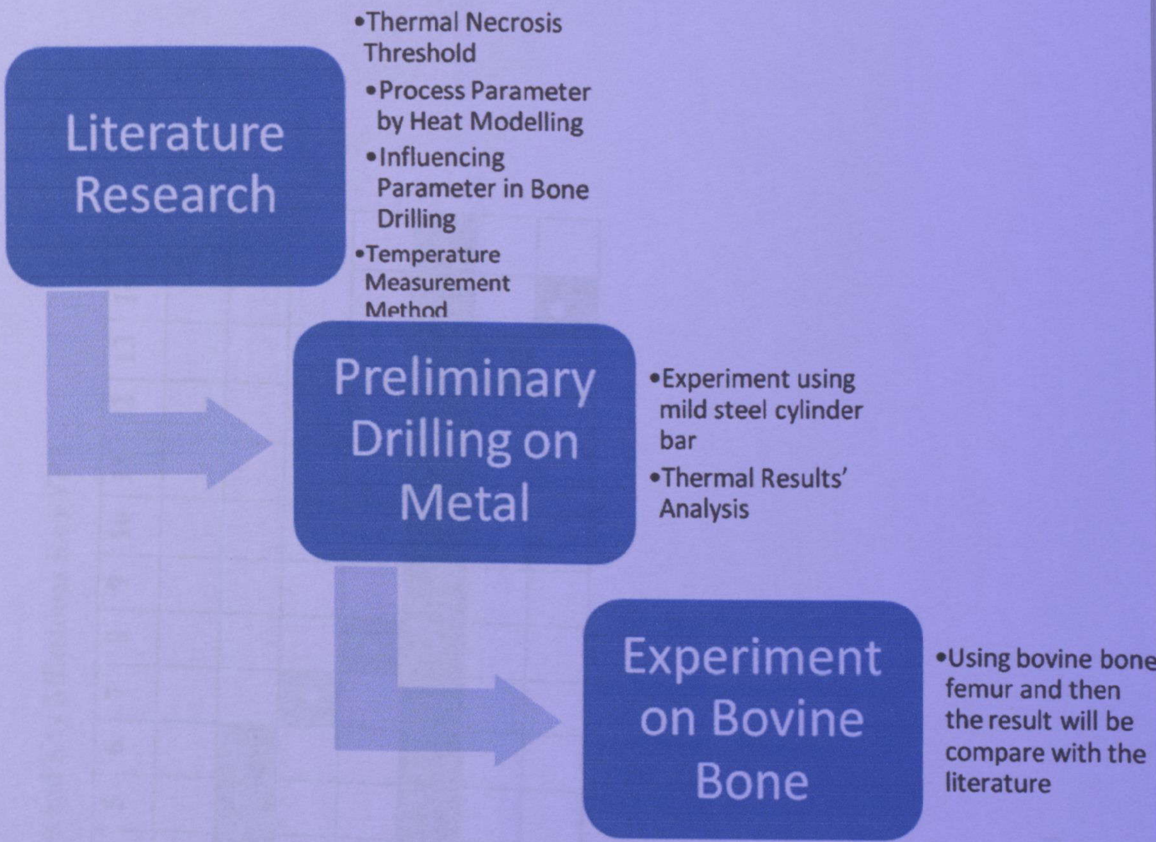

Figure 3.3.1 Key Milestone of the Project

3.4 Gantt Chart

Table 3.4.1 Project Activities and Key Milestones for FYP I

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Extended Proposal															
4	Proposal Defense															
5	Project work															
6	Submission of Interim Draft Report															
7	Submission of Interim Report															

Project Activity

Key Milestone

Table 3.4.2 Project Activities and Key Milestones for FYP II

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Project Work Continues																
2	Submission of Progress Report																
3	Project Work Continues																
4	Pre-SEDEX																
5	Submission of Draft Report																
6	Submission of Dissertation (soft bound)																
7	Submission of Technical Paper																
8	Oral Presentation																
9	Submission of Project Dissertation (Hard Bound)																

Project Activity

Key Milestone

3.5 Tools (Equipment and Hardware) Required

1. CNC Mazak VARIAXIS 630-5X
2. CNC Mazak INTEGREX 200-III
3. CNC Milling Trainer
4. Conventional Drilling
5. Band Saw
6. Abrasive Saw
7. Surgical Drills
8. Specialized Delta and U Drills
9. HSS Drill Bit
10. Thermocouples with Data Logger
11. Infrared Camera
12. Infrared Thermometer
13. Bovine Bone Femur
14. Aluminum Rectangular Bar
15. Mild Steel Cylinder Bar

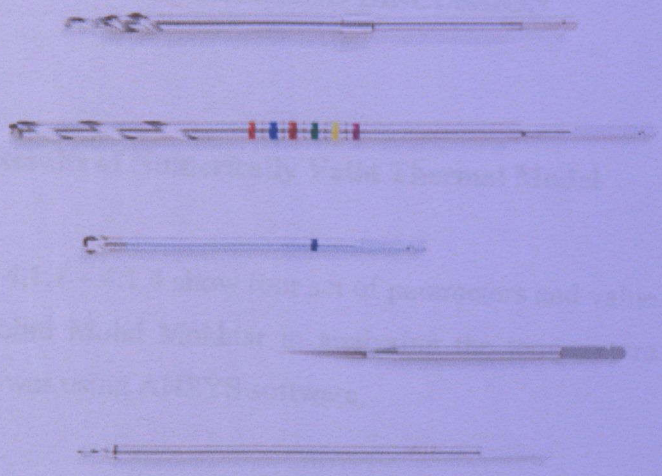

Figure 3.5.1: Surgical Drills and U Drills

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Thermal Results of Numerically Valid Thermal Model

The Table 4.1.1 – 4.1.4 show four set of parameters and value that been used by Munaibah binti Mohd Mokhtar in analyzing the temperature when drilling mild steel. She was using ANSYS software.

Table 4.1.1 Set 1

Parameters	Value
Drill diameter, mm	2.0
Drill speed, rpm	N=3000
Feed rate, mm/s	f3=2.2
Point angle	118°
Helix angle	23°
Chisel edge	do=0.01
Heat flux, W/m^2	3709

Table 4.1.2 Set 2

Parameters	Value
Drill diameter, mm	2.0
Drill speed, rpm	N=3000
Feed rate, mm/s	f3=2.2
Point angle	118°
Helix angle	23°
Chisel edge	do=0.01
Heat flux, W/m^2	2535

Table 4.1.3 Set 3

Parameters	Value
Drill diameter, mm	2.0
Drill speed, rpm	N=3000
Feed rate, mm/s	f=1.2
Point angle	118°
Helix angle	23°
Chisel edge	do=0.01
Heat flux, W/m^2	1433

Table 4.1.4 Set 4

Parameters	Value
Drill diameter, mm	2.0
Drill speed, rpm	N=3000
Feed rate, mm/s	f=0.42
Point angle	118°
Helix angle	23°
Chisel edge	do=0.01
Heat flux, W/m^2	534.2

Figure 4.1.1 shows the graph results of drilling speed (rpm) versus heat (J) with different feed rate (mm/s). The controlled variable is drill speed, the manipulated variables are feed rate, and the responded variable is heat.

Figure 4.1.1 Plot of Drill Speed versus Heat with different Feed Rate

From Figure 4.1.1, we can see that when the feed rate and the drill bit diameter increase, the heat also will be increase. These data will be a reference for mild steel cylinder bar drilling experiment procedure.

4.2 Thermal Results of Preliminary Drilling on Mild Steel Cylinder

Before the drilling experiment on bovine bone femur, there would be the preliminary drilling experiment on metal specimen. In the experiment and validation using metal specimen, temperature measurement method is crucial due to the comparison accuracy. Mild steel cylinder bar is used as the metal specimen in this experiment. Table 4.2.1 shows the literature of the general recommendations for drilling mild steel. The data in this table also will be a reference for mild steel cylinder bar drilling experiment procedure.

Table 4.2.1 Mild Steel Drilling Parameters [15]

Workpiece material	Mild Steel
Point angle, deg	118-135
Surface speed, m/min	20-30
Drill diameter, mm	1.5
Feed, mm/rev	0.025
Spindle speed, rev/min	4,300-6,400

I had done three experiments in measuring temperature in this project. The method in the first experiment is pointing the laser beam from the infrared thermometer to the drill point. The method in the second experiment is pointing the laser beam to the drill point with the emissivity 0.5 in the infrared thermometer. The method in the third experiment is pointing the laser beam at the distance of 5 mm from the drill point with same emissivity. Figure 4.2.1 shows the experimental setup for these experiments.

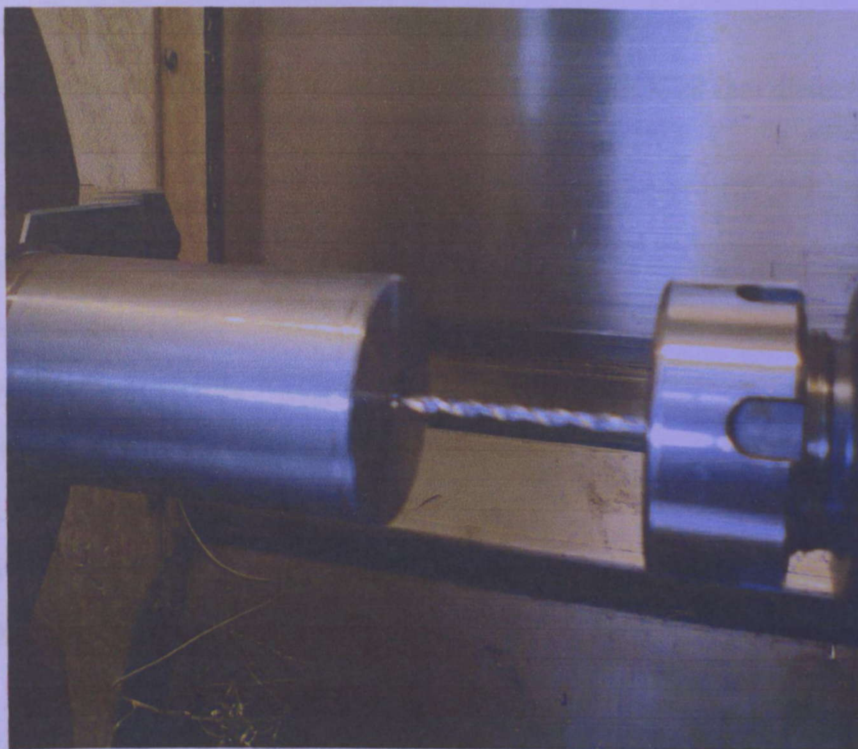

Figure 4.2.1 Experimental Setup for Mild Steel Cylinder Bar Drilling

The details for the first experiment are as follow:

- Workpiece: Mild steel cylinder bar; 100 mm length X 28 mm diameter
- Machine: CNC Mazak Integrex III
- Coolant: Disabled
- Drill bit: HSS; 2 mm diameter
- Point angle: 118^{O}
- Depth of cut: 10 mm
- Measure instrument: Infrared thermometer
- Room temperature: 19 ^{O}C
- Workpiece temperature before drilling: 20.3 ^{O}C
- Drill bit temperature before drilling: 20.7 ^{O}C

Table 4.2.2 shows the result from the first experiment.

Table 4.2.2 Result for the First Drilling Experiment on Mild Steel Cylinder Bar

Sample	**Spindle Speed (rpm)**	**Feed Rate (mm/rev)**	**Temperature (^{O}C)**
1	868	0.02	20.9
2	868	0.04	26.5
3	868	0.09	28.9
4	1287	0.02	24.6
5	1287	0.04	31.3
6	1287	0.09	34.4
7	4138	0.02	27.8
8	4138	0.04	32.6
9	4138	0.09	35.8

When compare this result with the result of numerically valid thermal model, it shows that the first experiment was failed. Because of this failure the second experiment need to be done. The details for the second experiment are same with the first experiment but with the additional of the infrared thermometer's emissivity that is 0.5. Table 4.2.3 shows the result of this experiment.

Table 4.2.3 Result for the Second Drilling Experiment on Mild Steel Cylinder Bar

Sample	Spindle Speed (rpm)	Feed Rate (mm/rev)	Temperature (^{o}C)
1	868	0.02	24.9
2	4138	0.09	29.7

With only these two temperature readings it can show that the second experiment also was failed. So the third experiment needs to be done. The details for the third experiment are same with the second experiment but the diameter of the mild steel cylinder bar is reduced to 20 mm and the infrared thermometer's laser beam is pointed 5 mm distance from the drill point. Table 4.2.4 shows the result of this drilling experiment.

Table 4.2.4 Result for the Third Drilling Experiment on Mild Steel Cylinder Bar

Sample	Spindle Speed (rpm)	Feed Rate (mm/rev)	Temperature (^{o}C)
1	868	0.02	24.3
2	1287	0.04	28.8
3	4138	0.09	30.6
4	4138	0.09	30.3
5	4138	0.09	30.7

The result for the third experiment also shows the failure.

4.3 Thermal Results of Drilling Experiment on Bovine Bone Femur

After my literature research and the interviews with Dr. Hasan Fawad, Munaibah binti Mohd Mokhtar, and Mohd Hafiz bin Safian, I have found that there are five main parameters that contribute to the temperature rises during drilling process. Those are:

1. Drilling spindle speed.
2. Drill bit diameter.
3. Drill bit point angle.
4. Drilling feed rate.
5. Bovine bone's properties.

One of the bone properties is brittle. One of the brittle materials is cast iron. Table 4.3.1 shows the general recommendations for drilling cast irons. The data in this table will be a reference for bovine bone femur drilling experiment procedure.

Table 4.3.1 General Recommendations for Drilling Brittle Material (Cast Irons) [15]

Workpiece Material	Cast Irons
Point angle, deg	118
Surface speed, m/min	20-60
Drill diameter, mm	1.5
Feed, mm/rev	0.025
Spindle speed, rev/min	4,300-12,000

For bone preparations and experiment technique, firstly bovine bone femur will be obtained fresh after slaughter. Secondly, this bone will be cut into two pieces. Thirdly, thermocouple will be installed between these two pieces and then these two pieces will be put back together using suitable glue. Fourthly, another thermocouple also will be installed in the U drill. We also will capture heat using thermal imaging camera. Lastly, the bovine bone drilling experiment can be started. Figure 4.3.1 shows roughly the design for bovine bone femur drilling experimental setup.

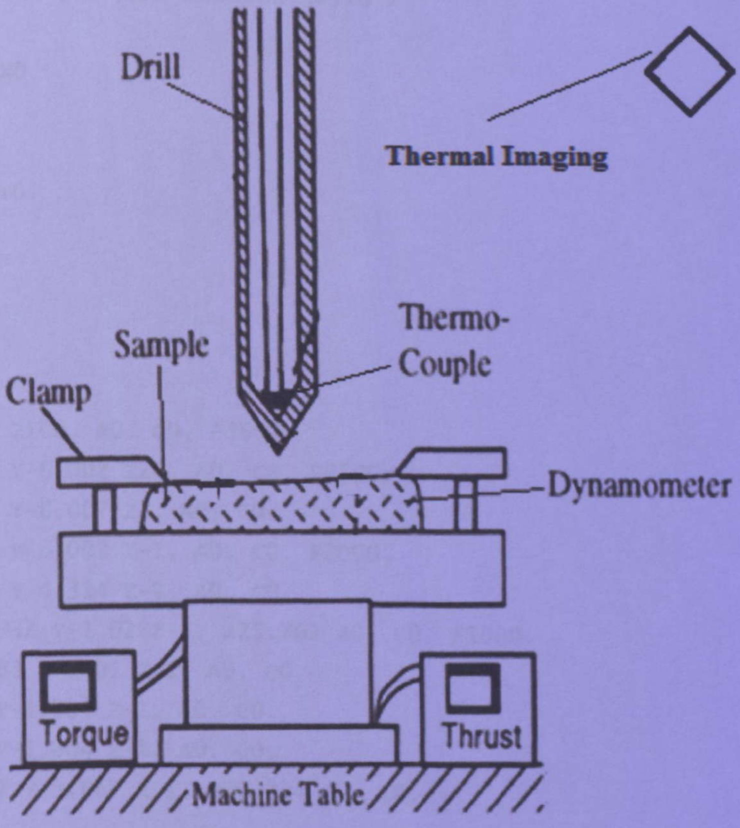

Figure 4.3.1: Rough Design for Experimental Setup

Actually the experimental setup for the bovine bone femur almost same with the experimental setup for the mild steel cylinder bar but the drilling experiment on bovine bone femur will be using CNC Milling instead of CNC Lathe that have been used in mild steel cylinder bar drilling experiment.

For clamping the bones sample on the machine, Mohd Hafiz bin Safian suggests the jigs and fixture for the bone. Below are the first ten lines of the programming to fabricate this jigs and fixture.

```
(NC OPERATION= CAVITY_MILL1  TOOLNAME= MILL12 )
( DIA= 12.0 CR= 0.0 FLAT ENDMILL _0jig )

G91G28Z0.Y0.X0.
T17M6
S2500M03
G90G00G58X0.Y0.
G43Z200.
G61.1
M8
G05P2

N12 G1 X0 Y0 Z100. A0. C0. F3500.
N13 X-73.696 Y-6.002 Z20. A0. C0. F2500.
N14 X-73.696 Y-6.002 Z2. A0. C0.
N15 X-73.696 Y-6.002 Z-1. A0. C0. F2000.
N16 X-70.696 Y-4.314 Z-1. A0. C0.
N17 G2 X-58.932 Y-1.02 Z-1. R25.761 A0. C0. F1000.
N18 G1 X-58.63 Y-1.01 Z-1. A0. C0.
N19 X-10.99 Y-1.004 Z-1. A0. C0.
N20 X57.148 Y-1.004 Z-1. A0. C0.
N21 G2 X69.47 Y-3.667 Z-1. R26.324 A0. C0.
```

Figure 4.3.2 shows the 3D drawing of this jigs and fixture. This drawing is using NX-3 software.

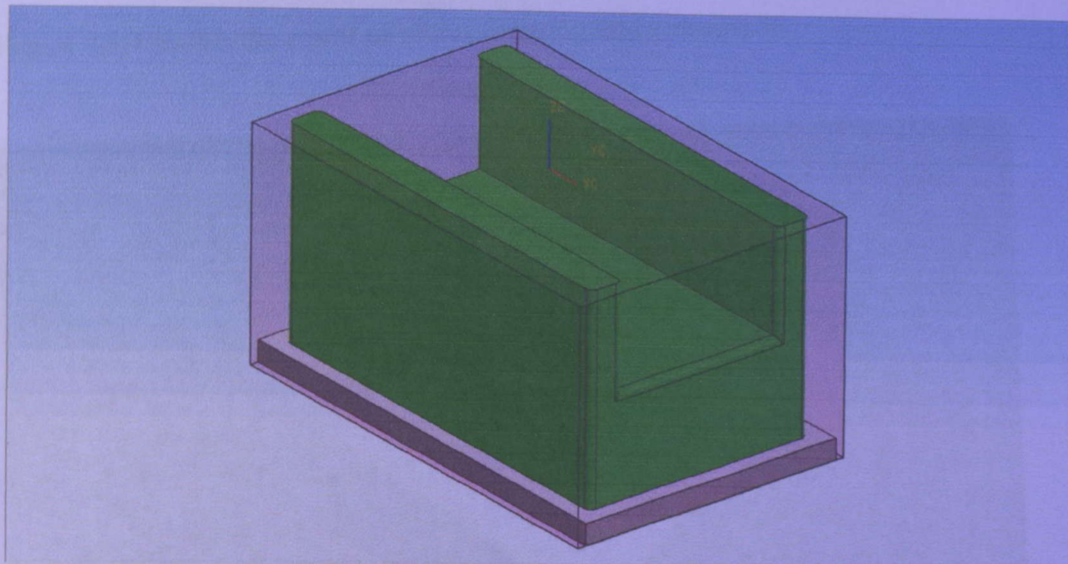

Figure 4.3.2 3D View of Jigs and Fixture

While Figure 4.3.3 shows the tool verification simulation of this jigs and fixture. This simulation also is using NX-3 software.

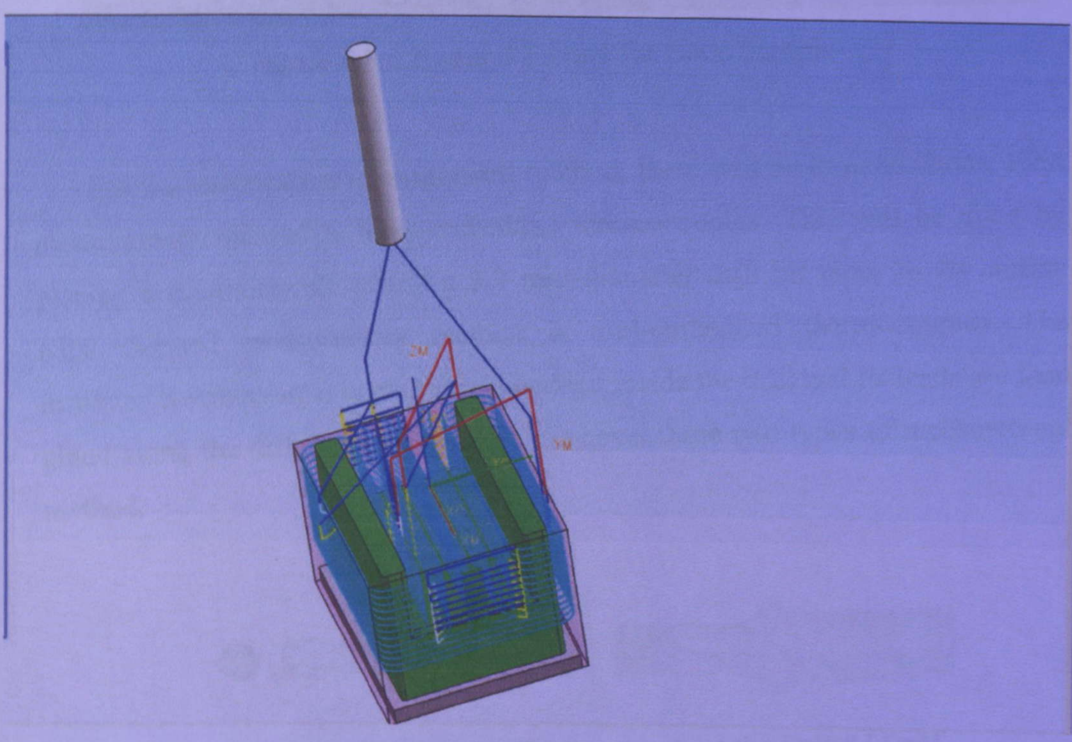

Figure 4.3.3 Tool Verification Simulation

Figure 4.3.4 shows the result of above drawing and simulation.

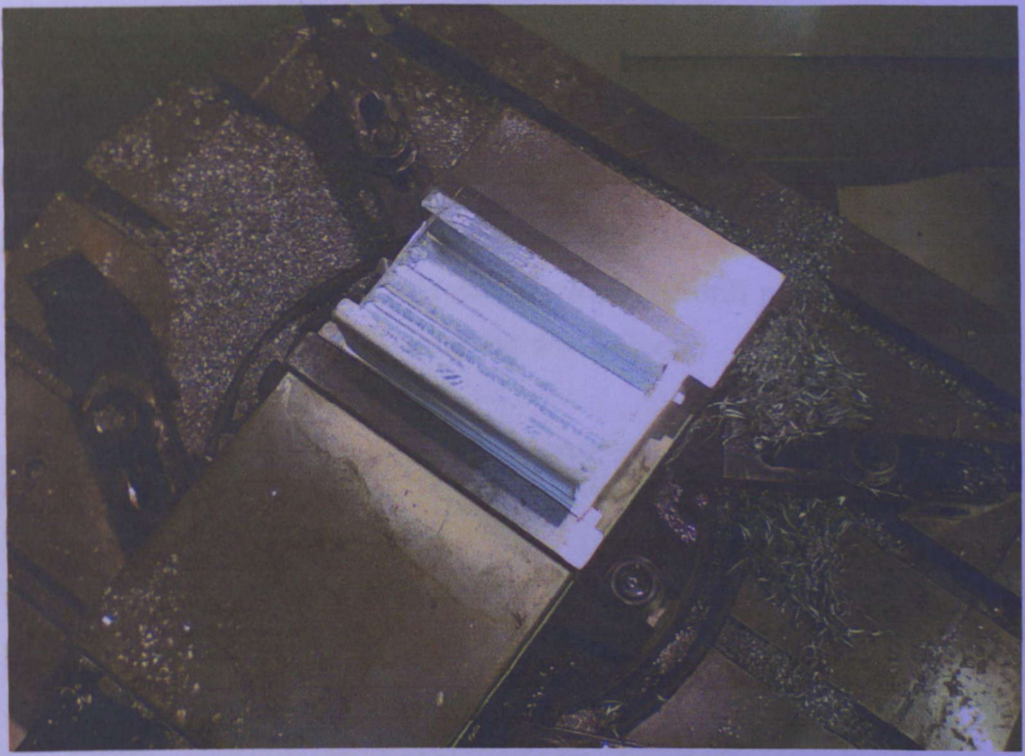

Figure 4.3.4 Jigs and Fixture for Bone Sample

For the temperature measurement method, there will be three methods. First measurement method is bone-embedded thermocouples. This will be done by placing a thermocouple inside a 3.2 mm diameter drill bit close to its cutting edge. Second measurement method is tool-embedded thermocouples. The insulated thermocouple is placed and bedded inside the drill and its leads are then glued along the drill barrel. Figure 4.3.5 shows these two types of measurement method.

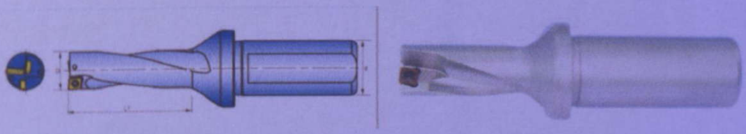

Figure 4.3.5 Bedding the Thermocouple at the Drill/U Drill

Third measurement method is thermal infrared imaging. Thermal pictures are recorded around the drilling areas. Infrared pyrometer is used.

I just did only one drilling experiment on bovine bone femur due to the time constraint. The method in this experiment was almost the same with the mild steel cylinder bar drilling experiment but this experiment used CNC Milling instead of CNC Lathe. The temperature measurement method in this experiment is pointing the laser beam at 5 mm distance from the drill point. Figure 4.3.6 shows roughly the experiment setup for this bovine bone.

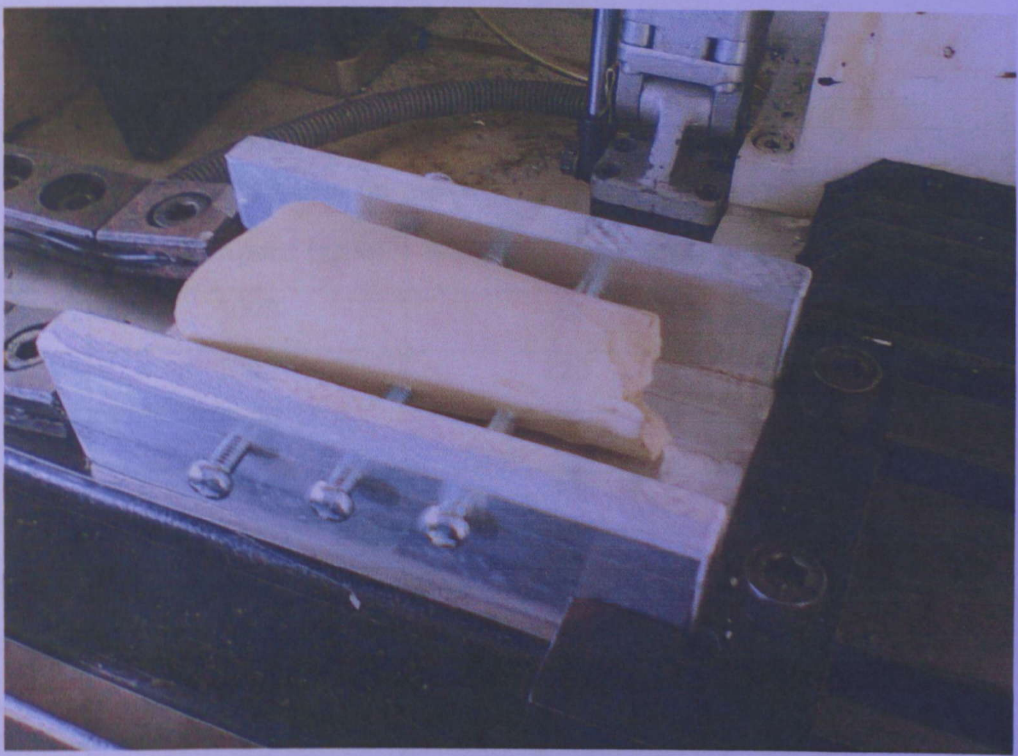

Figure 4.3.6 Experimental Setup for Bovine Bone Femur Drilling

The details for the experiment are as follow:

- Workpiece: Bovine Bone Femur
- Machine: CNC Milling Trainer
- Coolant: Off
- Drill bit: HSS; 2 mm diameter
- Point angle: 118^{O}
- Depth of Cut: 8 mm
- Measure instrument: Infrared thermometer
- Workpiece temperature before drilling: 12.5 ^{O}C

Table 4.3.2 shows the result for this experiment

Table 4.3.2 Result for the Drilling Experiment on Bovine Bone Femur

Sample	Spindle Speed (rpm)	Feed Rate (mm/min)	Temperature (^{O}C)
1	1000	42	16.5
2	1000	120	17.4
3	1000	220	17.7
4	2000	42	17.0
5	2000	120	18.1
6	2000	220	18.5
7	3000	42	17.7
8	3000	120	18.3
9	3000	220	18.6

According to Munaibah's analysis, she said that these temperature readings' results are very low for the thermal bone necrosis to occur because the maximum drill speed is only 3000 rpm. It should be increased until 200000 rpm to get the numerical results. Figure 4.3.7 shows the numerical result of valid thermal model by Munaibah.

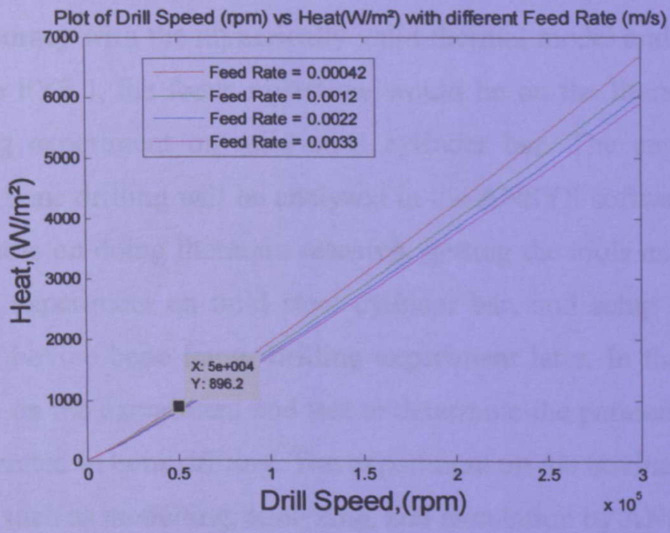

Figure 4.3.7 Plot of Drill Speed versus Heat with different Feed Rate

The comparison between my bone drilling experimental result with the above graph shows that my experiment was a failure.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In the drilling experiment of mild steel cylinder bar and the bovine bone femur, the temperature measurement method is very important due to the comparison accuracy with the numerically valid thermal model and the literature research. In the FYP I, the focus milestone would be on the literature research and the drilling experiment on mild steel cylinder bar. The analysis for the thermal bovine bone drilling will be analyzed in the ANSYS software. Basically, FYP I is just more on doing literature research, getting the tools and equipments needed, do the experiment on mild steel cylinder bar, and setup the tools and equipments for bovine bone femur drilling experiment later. In the FYP II, the focus would be on the experiment and test to determine the parameter that relate to the heat generated in bone drilling. The experiment on the bovine bone and the technical work such as modelling, analyzing, and simulation by ANSYS software will also be done.

As a conclusion for the numerically valid heat thermal model, the manipulated variables are drill speed and feed rate and the responded variable is heat. From the thermal results of numerically valid heat thermal model, we can see that when the feed rate and the drill bit diameter increase, the heat also will be increase. As a conclusion from the thermal results of preliminary drilling on mild steel cylinder bar, the temperature readings should be higher than those experimental values. These were happening because the sensitivity of the infrared thermometer. The remote sensor of the infrared thermometer is not precise and accurate enough to measure the temperature of the specimen.

As a conclusion for the drilling on bovine bone femur, the temperature readings are very low for the thermal bone necrosis to occur. The results should be higher than those experimental values. These were happening because the bones were kept longer than standard literature research. The bones should be kept within 48 hours after slaughter. Another reason is the sensitivity of the infrared thermometer. The remote sensor of the infrared thermometer is not precise and accurate enough to measure the temperature of the specimen.

In term of industry, this project would enhance the medical field especially in the orthopaedic sector. The analysis would help doctors in their works and maintaining the consistency of their skills especially in drilling bones. The 'Thermal Analysis of Bovine Bone Drilling' would provide the information on how to control the parameters of bone drilling.

In term of community, this project also will benefit people by lowering the probability of having thermal bone necrosis. Accidents that cause bone fracture trauma can happen every day, thus having the up to date controlling parameter that minimize the injury occur in the bone would benefits all genre of society.

Further research and experiment are needed to analyse the thermal effects of bone in order to ensure the bone's strength is not affected. I recommend better bone sample preparation technique and better temperature measurement device to get more accurate temperature readings in order to compare with the numerically valid thermal model and also with the literature research.

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17. Dr. Hasan Fawad, Senior Lecturer of Mechanical Engineering Department, Universiti Teknologi PETRONAS.

18. Munaibah binti Mohd Mokhtar, Master Science Student, Universiti Teknologi PETRONAS.
19. Mohd Hafiz bin Safian, Technician of Manufacturing Section, Mechanical Engineering Department, Universiti Teknologi PETRONAS.