SUPERVISOR DECLARATION

I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure and Materials)

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Date: ………………………..

EXPERIMENTAL STUDY OF FEMUR BONE UNDER NORMAL LOADING

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This report is submitted to fulfil the requirement of the Bachelor in Mechanical Engineering (Material and Structure)

Faculty of Mechanical Engineering
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MAY 2012

DECLARATION

"I hereby declared that the work in this report is my own work except for the quotations which have been duly acknowledged"

Signature: ………………………………

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Date: ………………………………

Specially dedicated to my loving parents,
my great and good-hearted supervisor,
my cheerful siblings and my supportive friends.

ACKNOWLEDGEMENT

Alhamdulillah, I praise to Allah S.W.T. for His Blessings during the development of this project.

I would also like to owe my appreciation toward my final year project supervisor, Dr. Mohd. Juzaila bin Abdul Latif for the opportunity to be under his great supervision. I am able to learn new fields which are biomedical and biomechanics as I working on this project. With his guidance, I managed to do the project successfully according to the requirements for the final year project from the university.

I would also want to extend my deepest gratitude towards UTeM staff, especially Mr. Mohd. Hairuddin bin Kanan and Mr. Kamaruddin bin Abu Bakar, technicians that helped me in developing the femur bone prototypes. Not forgotten, Mr. Muhammad Muzaini bin Sahary, Mr. Faizol bin Kamarol Zahari, Mr. Mohd. Faizal bin Zailani, Mr. Wan Saharizal bin Wan Harun, Mr. Mohd. Hairi bin Md Rahim and Mr. Mazlan bin Tumin who helped me a lot in the setting up the experiment. I would also like to give very much appreciation to my family and my friends for the direct and indirect involvement in helping me to complete this project. Without all of them, my project will not succeed. Thank you very much.

ABSTRACT

The mechanical stress determination in human femur bone is of great importance in both research and clinical practice. One of the methods to estimate the stress is through finite element modeling. In spite of that, the modeling technique has to be validated by an experimental approach as it is the best tool to assess the accuracy of the finite element model predictions. However in the previous studies, this validation has not been carried out extensively due to limited number of studies available and the difficulties of the experiment procedure. The aim of this project is to develop an experimental method in order to determine the maximum stress at the surface of the bone prototype under normal loading. An experiment is conducted where load is applied at the femoral head and maximum stress on the bone surface is determined with the presence of strain gauges.

ABSTRAK

Penentuan tegasan mekanikal di dalam tulang femur (paha) manusia adalah amat penting dalam penyelidikan dan amalan klinikal. Salah satu kaedah untuk mengganggarkan tegasan ini adalah melalui permodelan unsur terhingga. Walau bagaimanapun, teknik permodelan ini perlu disahkan dengan pendekatan uji kaji kerana ia merupakan teknik terbaik untuk mengkaji ketepatan ramalan model unsur terhingga. Di dalam kajian sebelum ini, pengesahan ini malangnya tidak dapat dijalankan secara meluas disebabkan oleh bilangan kajian yang terhad dan kesukaran langkah-langkah eksperimen. Projek ini bertujuan untuk menghasilkan kaedah uji kaji untuk menetukan tegasan maksimum pada permukaan prototaip tulang femur di bawah pembebanan biasa. Satu eksperimen dijalankan di mana beban yang dikenakan di kepala tulang femur dan tegasan maksimum pada permukaan tulang femur akan ditentukan dengan kehadiran tolok terikan.

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σ	=	Stress, MPa
ε	=	Strain
F	=	Load, N
δ	=	Deformation
A	=	Area, m^2
L	=	Length, m
E	=	Young's Modulus, MPa
v	=	Poisson's Ratio
$\mu\varepsilon$	=	microstrain
GF	=	Gauge Factor
ΔR	=	Change in Resistance, Ω
R	=	Resistance, Ω
K_t	=	Transverse Sensitivity, %
$>$	=	Larger than
$<$	=	Smaller than
ε_a	=	First Element of Strain Gauge
ε_b	=	Second Element of Strain Gauge
ε_c	=	Third Element of Strain Gauge
ε_1	=	Strain Gauge at Location 1
ε_2	=	Strain Gauge at Location 2
ε_3	=	Strain Gauge at Location 3

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Femur bone is a bone between the hip and the knee joints. It is one of the longest, and the strongest bone of human skeleton. However, femur bone can experience fracture if tremendous force is applied onto it. Femur bone can also be weakened by disease such as osteoporosis and arthritis. In biomedical, the surgical techniques used for femur fracture treatments need to be simulated using computer in order to evaluate the performance of the implants. Then the simulation will be validated by experimental approach as experimental validation is the best tool to evaluate the overall accuracy of finite element model previsions.

1.2 PROBLEM STATEMENT

In previous studies, this validation has not been carried out extensively due to limited number of studies available in the literature and the difficulty of the experiment procedure.

1.3 OBJECTIVES

The objective of this project is to use and to develop an experimental method of femur bone to determine the maximum stress at the surface of the bone under normal loading.

1.4 SCOPE

In order to achieve the objective above, this project will focus to:

a) collect validated geometrical data of femur bone
b) develop 3D solid model of femur bone (prototype) using rapid prototype machine
c) conduct an experiment of the femur bone prototype under normal loading to determine the stress on the bone's surface
d) apply suitable solid mechanics theory for result comparison

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The femur is a long bone whose axis of movement is well outside of its substance for most of its length. It is located between the hip and the knee. Its rounded, smooth head fits into a socket in the pelvis called the acetabulum to form hip joint (an example of ball-and-socket joint). The head of the femur is joined to the bone shaft by a narrow piece of bone known as the neck of the femur. The femur neck is a point of structural weakness and a common fracture site. The lower end of the femur hinges with the tibia (shinbone) to form the knee joint. The structure of femur bone is shown as in Figure 2.1.

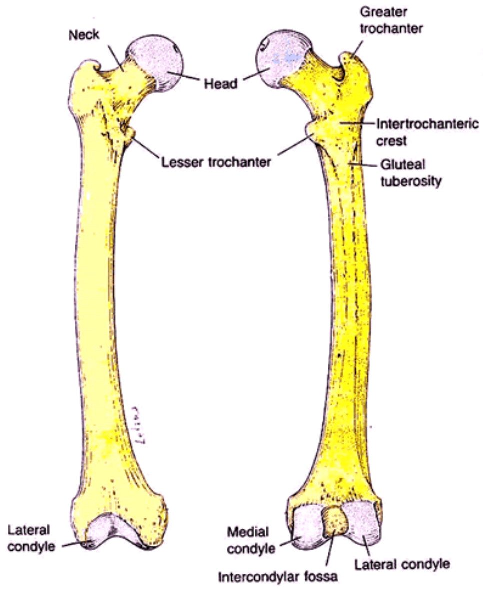

Figure 2.1 Femur bone

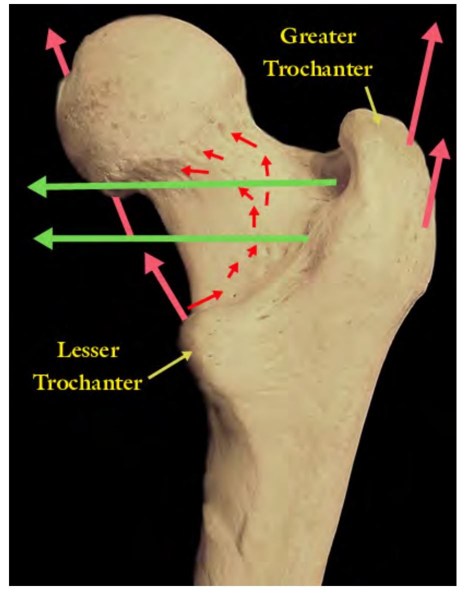

Figure 2.2 Femur upper end

On the outer side of the upper end of the femur (Figure 2.2) is a protuberance called the greater trochanter. The gluteus and psoas muscle are inserted on the greater and lesser trochanter, respectively. The greater is the handle for upward pulling hip abductors (gluteus medius and minimus). The lesser is the handle for the psoas tendon. As located behind the femoral head, the flexion action of the psoas is also an outward rotation force as the lesser trochanter is pulled forward and upward (spinning and raising the femur). The femoral neck-shaft angle is located between long axes of the femur neck and the shaft of the femur. The range is normally between 125˚ - 135˚. This angle is necessary for the hip joint normal functions.

The sweep of short red arrows indicates that an important bundle of blood vessels sneaks up the back of the neck on its outer surface to enter the femoral head. This in-flow of blood is important for femoral head. Shearing of these vessels will leave the head without blood supply in part or in whole. For adult, the avascular femoral head becomes necrotic (dies) and is called avascular necrosis. However, for a child, as a goodly portion of the head is still cartilage which does not nourish from blood vessels, the necrosis only involves the bone portion. It is called perthes.

At the lower end, the bone is enlarged to form two lumps called the condyles that distribute the weight-bearing load on the knee joint (Figure 2.3). The lateral and medial epicondyles articulate with the tibia and the trochlear groove accommodates the patella (kneecap). The distal end of the femur is one of the four boney parts of the knee. The others are tibia, patella, and indirectly (by being a ligament handle) the fibula.

Outer (lateral) Front (anterior) Inner (medial) Back (posterior)

Figure 2.3 Shapes of femur lower end

2.2 FEMUR BONE STRUCTURE

There are two types of bone can be distinguished generally; compact bone and cancellous bone. These two types of bone differ by depending on the relative amount of solid matter and the spaces they contain. The inner structure of femur bone is shown as in Figure 2.4.

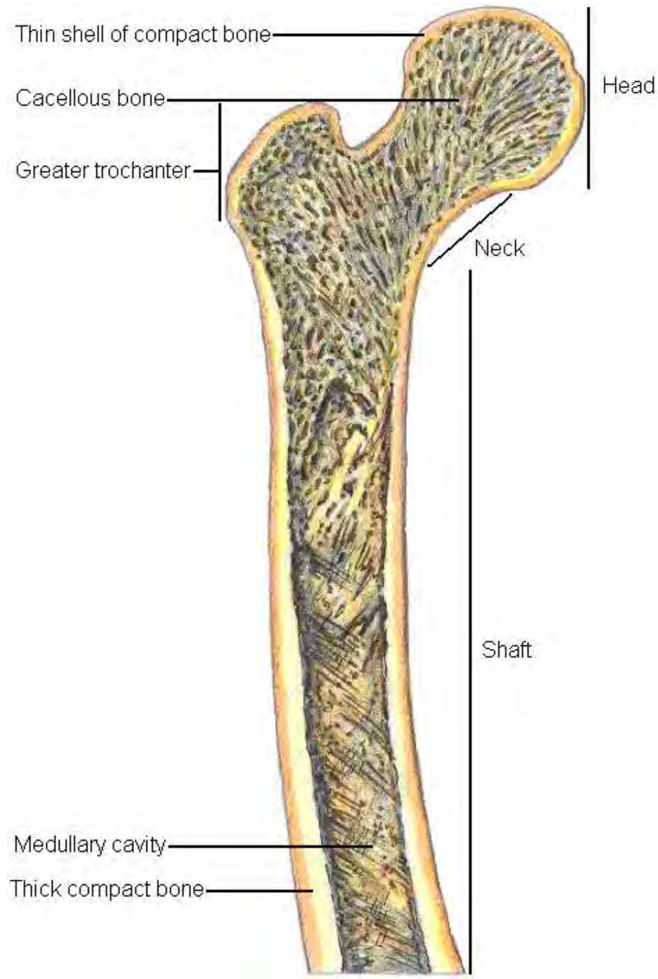

Figure 2.4 Femur bone inner structure

2.2.1 Compact Bone

The compact bone is also known as cortical bone forms the outer shell of bone. It is thicker at the femoral shaft and thinner at both of femur ends. Compact bone is denser compared to cancellous bone which allows for greater mineralization but less flexibility. The number, size and degree of mineralization of the osteons affect the way compact bone responds to loading. It also provides strength for weight bearing. This type of bone is surrounded by a thick fibrous layer of connective tissue containing blood vessels called periosteum which is responsible for nutrition of the underlying bone, and lined by a single layered epithelium in the internal surface called endosteum which takes part in formation of new bone. The portion of femoral shaft is shown as in Figure 2.5.

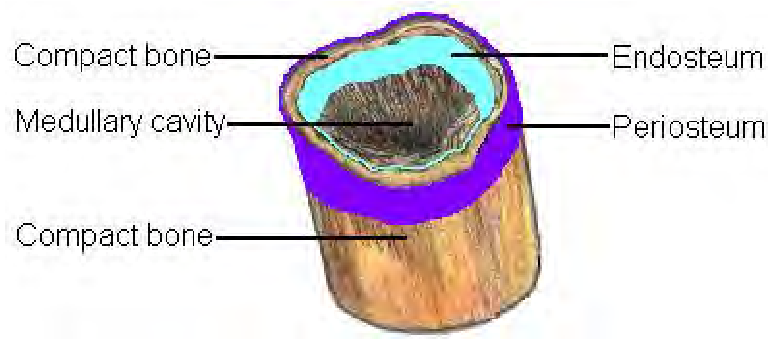

Figure 2.5 Portion of femoral shaft

2.2.2 Cancellous Bone

Cancellous bone is also known as spongy bone or trabecular bone located in the interior of the bone and is always surrounded by a thin shell of compact bone. In femur, it is present at both ends. Cancellous bone is less compact but with high porosity. It consists of a network of rods and bone plates called bony spicules or trabeculae. The spaces between spicules are filled with blood vessels and bone marrow. The arrangement of the bony spicules will change if there is alteration in the strain exerted on the cancellous bone. Due to the differences in porosity, the energy absorbing capacity of this type of bone is different from the compact bone.

2.3 HEALTHY AND UNHEALTHY FEMUR BONE

Femur bone is the largest and strongest bone in the human body. It is designed to give human stability. Femur bone will need a very powerful force before it can experience fractures.

The strength of bone is related to bone mass and the apparent density of the bone, which is related to its mineral content (Gomez and Nahum, 2002). Weaker bone, or bone with lower bone strength and lower bone density, will potentially fracture at lower levels of force (Dabezies and Warren, 1997).

Healthy or normal femur bone has a dense, thick envelope (cortex). The cancellous bone is evenly distributed with the trabeculae oriented in the form of an arch. The envelope is very strong and can withstand a force of one tonne per cm^2. On the other hand, unhealthy bone or osteoporotic femur bone has thinner envelope. The more serious the osteoporosis, the more fragile the cortex. The content loses its trabeculae and those remain will fracture easily. Structure difference between normal and osteoporotic femur bone is shown as in Figure 2.6.

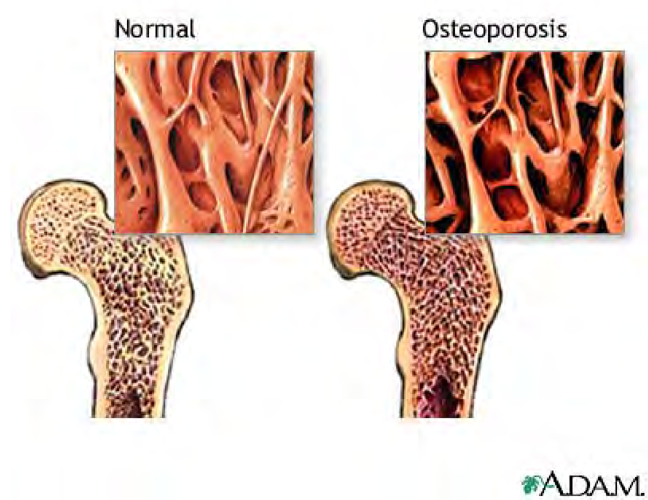

Figure 2.6 Normal and osteoporotic femur bone

2.4 FEMUR FRACTURES

In order for a femur fracture to occur, a large force must be applied or something is wrong with the bone. For human with normal bone strength, the most common causes of femur fractures are car accidents and falls from a height. Human may also have bone that is weakened by osteoporosis, tumor, or infection. Femur fractures are generally separates into three broad categories; proximal femur fracture, femoral shaft fracture and supracondylar femur fracture.

2.4.1 Proximal Femur Fracture (Hip Fracture)

Proximal femur fracture involves the upper-most portion of the thigh bone, just adjacent to the hip joint. This type of fracture, often called a broken hip is commonly in elder people, especially in women suffering from osteoporosis and is associated with a fall.

In a fracture of the neck of femur, the broken bone ends are often considerably displaced; in such cases there is usually severe pain in the hip and groin (made worse by movement) and the leg cannot bear any weight. Occasionally, the broken ends of the bone become impacted (wedged together). In this case there is less pain and walking is often still possible, which may delay reporting of the injury and detection of fracture. Hip fracture is generally separated into two types of fracture:

1) Femoral Neck Fracture

Occurs just below the ball of the ball-and-socket hip joint; this region is called femoral neck. When a femoral neck fracture occurs, the ball is disconnected from the rest of the femur. The blood supply to the fractured portion of bone is often disrupted at the time of injury. Because blood flow is diminished, these fractures are at high risk of not healing, especially when the fracture is badly displaced.

2) Interrochanteric Hip Fracture

Occurs lower than femoral neck fracture. This type of fracture does not have any issue with damage to blood flow to bone seen with the femoral neck fracture. Figure 2.7 shows the difference between femoral neck fracture and interrochanteric fracture.