NUMERICAL ANALYSIS OF FATIGUE LIFE PREDICTION OF TRABECULAR BONE RESPECT TO PHYSIOLOGICAL ACTIVITIES(NORMAL WALKING)

MOHAMMAD MOSTAKHDEMIN

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This thesis is dedicated to all my dear family

My father, thank you for your endless support and encouragement and your energized manner.

My mother, thank you for touching my heart and showing me the light when I turn to you.

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ABSTRACT

Osteoporosis disease makes bone fragile and weak to withstand against load and bodyweight. Crack initiation and damage might occur depends on different morphological indices and types of load impose on trabecular bone. Fatigue analysis with strain-based method is applied for bovine trabecular bone with three different morphological indices to investigate correlation between fatigue life results and bone morphology. Two different analyses were performed, the first was static and the second was dynamic analysis. Axial load imposed on vertical, 45-degree and horizontal samples. Plastic strain in vertical sample initiated at 30% of total and reach to 5.97e-4 at 40% however, at 45-degree and horizontal initiated at 20% and 10% with values of 0.00479 and 0.211 respectively. Then fatigue analysis was performed on samples and S-N curve extracted. Results shows that fatigue life of vertical sample at high load amplitude (40% of total load) is 12262 cycles, however this value in 45-degree and horizontal samples decrease drastically to 357 and 5 cycles respectively. In the various morphological indices, BV/TV and BS/TS are counted as crucial factor in correlation between fatigue life and bone morphology. Vertical sample include of less porosity than 45-degree and horizontal, and because of this reason stress localized and plastic strain value in vertical sample value is far below than other two. Fatigue life decrease when porosity of structure increases. Plastic strain and high stresses had been appeared in arch and rod-like of trabeculae.

ABSTRAK

Osteoporosis menjadikan tulang semakin rapuh dan lemah untuk menahan risiko beban dan berat badan. Permulaan keretakan dan kerosakan mungkin berlaku bergantung kepada yang perbezaan bentuk morfologi dan jenis beban yang dikenakan ke atas tulang trabekular. Analisis kelesuan dengan kaedah berasaskan keterikan digunakan untuk tulang trabekular sapi dengan tiga berbeza bentuk morfologi untuk menyiasat hubungan antara keputusan hayat lesu dan morfologi tulang. Dua analisis yang berbeza telah dilakukan; yang pertama adalah statik dan yang kedua adalah analisis dinamik. Beban paksi telah dikenakan ke atas sampel pada arah menegak, 45 darjah dan mendatar. Terikan plastik pada sampel arah menegak bermula pada 30% daripada jumlah beban dan mencapai ke 5.97e-4 pada 40%. Walau bagaimanapun, pada arah 45 darjah dan mendatar, terikan plastic bermula pada 20% dan 10% dengan nilai 0.00479 dan 0.211. Kemudian, analisis kelesuan telah dijalankan ke atas kesemua sampel dan lengkung S-N di ekstrak. Hasil menunjukkan bahawa hayat lesu sampel arah menegak pada beban beramplitud maximum (40% daripada jumlah beban) adalah 12,262 kitaran, namun nilai ini berkurang secara drastik pada sampel arah 45 darjah iaitu 357 kitaran dan sampel mendatar dengan 5 kitaran. Dalam pelbagai bentuk morfologi, BV / TV dan BS / TS dikira sebagai faktor penting dalam hubungan antara hayat kelesuan dan morfologi tulang. Sampel arah menegak yang juga kurang keliangan berbanding sampel arah 45 darjah dan mendatar, menyebabkan tekanan lokal dan nilai terikan plastik jauh lebih rendah berbanding sampel lain. Hayat lesu berkurang dengan bertambahnya keliangan pada struktur tulang. Terikan plastik dan tegasan tinggi tampak di lengkung dan rod tulang trabekular.

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LIST OF ABBREVIATIONS

BS	-	Bone Surface Area
BV	-	Bone Volume
BV	-	Bone Volume
BV/TV	-	Volume Fraction
CAD	-	Computer aided design
CT	-	Computer Tomography
FEM	-	Finite Element Method

HU	-	Hounsfeild Unit
S-N	-	Strain Amplitude- Number of Cycles to Failures
STP	-	Standard Temperature and Pressure
TS	-	Total Surface Area
TV	-	Total Volume

LIST OF SYMBOLS

A	-	Cross section areas
b	-	Fatigue strength
c	-	Fatigue ductility exponent
E	-	Young's modules
G	-	Shear modulus
J	-	Polar Moment
K	-	Strength coefficient

k	-	Torsional Stiffness
l	-	Current gage length
l_0	-	Initial gage length
n	-	Strain hardening exponent
N_f	-	Number of Cycles to Failure
N_t	-	Transition fatigue life
P	-	Pressure
S	-	Engineering Stress
T	-	Torque
$\sigma_{f'}$	_	Fatigue strength coefficient
$\varepsilon_{f'}$	_	Fatigue ductility coefficient

CHAPTER 1

INTRODUCTION

1.1 Introduction

These days analysing parts of body is highlighted due to increasing of survival humanity. Since there are movements in body, some parts such as bones, joints and muscles are involved in this investigation. Among such these parts, trabecular bones play an important role in skeleton structures for their duties. One of the most important duties of skeleton is tolerating body weight during physiological activities such as gait, walking, running and downstairs loading; but the point is, most percent of this loading is being withstood by especial structures inside the bones which is called trabecular bone (Spongy bone). For predicting life of the trabecular bone, some analysis should be considered which could be numerical, analytical and experimental analysis. In this study numerical analysis has been performed t predict fatigue life of trabecular bone subjected to axial loading. However, when femoral head part in vivo is subjected to bodyweight and physiological activities, because of its angle and load imposed on it, trabecular bone is faced with this type of load in various angle. In this analysis this angle is considered as vertical model, 45-degree and horizontal model. Stress analysis first is performed, then fatigue analysis and number of cycles to failure for trabecular bone is calculated This chapter covers the problem background, problem statement, objectives and scope of study.

1.2 Objectives

i. To predict fatigue life of bone structure,
ii. To analyse the fatigue behaviour of the Trabecular bone respect to physiological activity (Normal Walking), subjected to axial loading
iii. To study relationship of morphology indices with fatigue life of bone structure.

1.3 Problem Statement

Most of the researchers looking forward to find some methods for analysing bone structure by which can replace the artificial bone instead of the real one. These methods is used to apply mechanical properties obtained from experimental part to predict the fatigue life of bone structure and its behaviour respect to different physiological activities, then analyse the fatigue life in different anatomical sites to understand correlation between different morphological indices and fatigue life of trabecular bone.

Considerably, trabecular bone makes useful contribution all over the body because of load tolerating duty. However, highly percent of stress distribution are tolerated by trabecular bone. The point of such research is to know, how the stresses due to physiological activities loads distribute over the bone and to what extend these stresses influence on fatigue life. Fatigue life prediction based on different anatomic sites and find correlation between different morphologies and fatigue life is highly demand in this project.

1.4 Scope of Project

First scope of this project is to reconstruct the trabecular bone structure in effective quality to prepare it for mechanical analysis. Since there is high-tech system such as Micro-CT scanner, which assists to construct the complex structures by using especial software called Materialize mimic software. Mimic is able to have link with those images taken from Micro-CT scan and construct any 3D-complex structure such as trabecular bone which cause have trustworthy results in the pre-processing step in FE software that strongly influence in the final results.

The second scope of this project is to fatigue analysis by using FE package. Researchers make their effort to use some methods to get their result such as experimental, analytical and numerical methods. In this project numerical analysis is selected to simulate fatigue life prediction. Experimental study of project is not inconsistency with numerical analysis; however most of the research is based on the experimental method and then being validated by numerical or analytical methods. In addition, numerical analysis with COMSOL Software will help to find required parameters in this project. In the next step this results will be validated by experimental test obtained from previous studies.

Third scope of this project is to compare the fatigue behavior of trabecular bone with various anatomical sites with different morphological indices. Apply various parts of trabecular bone in body respect to different physiological activities and different morphological indices clear that to what extend bone indices influence on the whole structure and this is the way to get idea for construct idealize structure and use it in the body as artificial structure.

1.5 Significance of Project

The first significance of this study is considering the mechanical properties in common physiological activities. Gait loading is known as one of the common activities that everyone is involved with it all the days; In addition, due to the fast life, common diseases among people are common such as obesity. Analysing fatigue life of trabecular bone based on average bodyweight in this decade, make it useful contribution for human being and their health, especially for those who suffered from obesity.

The second significance of this study is to know to what extend various types of loading due to various daily activities strongly influence on the bone structures and which of them cause do damage more. Among various loading, cyclic loading and monotonic loading in the axial and torsional condition could be playing an important role to damage bone.

Fatigue life prediction of trabecular bone and using FE package cause estimate the crack initiation and crack growth and its location based on strain accumulation analysis; there are current problems which should investigate according to the common physical activities. Osteoporotic fracture also is one of the famous diseases occurring due to the excessive loads on the bone.

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