IRF'2009, Porto 20-24 July 2009

INTEGRITY RELIABILITY AND FAILURE

CHALLENGES AND OPPORTUNITIES

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Published by

INEGI-Instituto de Engenharia Mecânica e Gestão Industrial
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Tel:+351 22 957 87 10; Email: inegi@inegi.up.pt
www.inegi.up.pt

July, 2009

ISBN: 978-972-8826-22-2
Legal D.N: 295639/09

Printed by:

LusoImpress (Grupo Claret)
Rua Venceslau Ramos, s/n – 4430-929 Avintes, Portugal
Tel:+351 22 787 73 20; Fax:+351 22 787 73 29

PREFACE

As the engineering community continues to cross the boundaries of known practices, materials and manufacturing techniques into the frontiers of new functional materials, environments and applications, the opportunities for catastrophic failures will inevitably increase. If our knowledge of how to engineer systems, structures and components to minimize or prevent catastrophic failure is to keep pace with modern manufacturing technologies, the demanding applications, and the intolerance of a safety conscious society, we must continue our efforts to develop and use superior materials, apply reliable analytical techniques and validate these with sound experimental tools.

The objective of this gathering is to provide a forum for the discussion and dissemination of recent advances in three related areas: integrity, reliability and failure of engineering structures, components and systems. The goal is to enable mechanical, aeronautical, civil, automotive, biomedical and nuclear engineers, researchers and scientists from all over the world to exchange ideas on mechanics, materials and design as they relate to system integrity and reliability.

This third international conference was part of a prestigious series of Integrity Reliability and Failure conferences coordinated by the International Scientific Committee on Mechanics and Materials in Design. The conference attracted over 260 participants with 310 accepted academic and industrial submissions from 45 different countries around the world. These papers were presented in July 20–24, 2009 in the magnificent city of Porto, Portugal, and the conference themes focused on design, nanotechnology, computational and structural mechanics, experimental mechanics, advanced materials, energetic systems, and case studies.

We are particularly indebted to the *Symposium Promoters* for the coordination of the different themes and to the authors for their papers and oral presentations. Each of the more than 300 oral contributions offered opportunities for thorough discussions with the authors. We acknowledge all of the participants, who contributed with innovations, new research approaches, novel modelling and simulation efforts, and invaluable critical comments.

We are also indebted to the six outstanding plenary lecturers who highlighted the conference themes with their contributions: Dr. J.N. Reddy (Texas A&M University/USA), Dr. Shaker A. Meguid (University of Toronto/Canada), Dr. G. Weng (Rutgers University/USA), Dr. D.R.J. Owen (University of Swansea/UK), Dr. Magnus Langseth (NTNU/Norway), and Dr. Mário A.P. Vaz (University of Porto/Portugal).

Finally, we wish to express our gratitude to the members of the International Scientific Committee for reviewing the papers and to the Conference Organizing Committee: Dr. Carlos C. António, Dr. José M. Cirne, Dr.Rui M. Guedes, Dr. M. Teresa Restivo, Dr. Aarash Sofla, and Dr. Mário A.P. Vaz.

Shaker A. Meguid & J.F. Silva Gomes

Porto, July 2009

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REF: S1904_A0345

HUMAN FEMUR ASSESSMENT USING ISOTROPIC AND ORTHOTROPIC MATERIALS DEPENDENT OF BONE DENSITY

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SYNOPSIS

The bone mass reduction and the deterioration of the tissue micron-architecture lead to a bigger fragility of the bone and to the consequent increase of the fracture risk. For this fact, it is considered excellent the quantification of the mass density and the verification of its influence in the bone resistance assessment. The apparent density is defined as the density without fluid influence, being the effective density at that includes the marrow mass, essentially fluid. This measurement is made through the use of a gray scale values on the medical image in study. The values in Hounsfield units are determined, being this scale later converted into measure of the bone density. With this measure an exponential relation will be used allowing calculate the biomechanics properties dependence for cortical and trabecular bone. With this work it is intended to assessment the susceptible weak zones, for a human femur with 70 years old, using the finite element method through ANSYS® program. The main objective is obtaining the stresses distributions, using different values of bone density and their relation with exponential laws for isotropic and orthotropic materials properties.

INTRODUCTION

The finite element method has been used in biomechanics studies through the simulation of some anatomical structures. Some authors have come to dedicate their works in this area, through numerical simulations of human femur using solid models (Baca, 2008), (Taylor, 1996), for example. Also, in the experimental area, they have been published results from (Bergmann, 2001), (Simões, 2004). Some authors, (Baca, 2008), (Peng, 2006), have used different numerical simulations with isotropic and orthotropic constituent models, for bone tissues. The biomechanics properties depend on structural aspects of the bone, its bone geometry, but also on intrinsic properties of the material, between which, the bone density. Particularly, the bone density keeps one strong inverse relation with the risk of bone fracture (Augat, 2006). The objective of this work is to produce one numerical femur model, constituted of different cortical and trabecular bone layers, through the effective density measurement under medical image. The study will be developed with the previous medical image treatment, gotten of one male femur with 70 years old. Pre-processing and treatment techniques were used for the study of medical image. The femur model is converted into 3D CAD format being later used in a biomechanics numerical simulation.

RESULTS

Figure 1 represents the study of human femur using the finite element method. For results calculation, two anatomical plans were considered under different bone tissue densities. Horizontal plan (h) AMPL represents the zone of Previous, Medial, Posterior and Lateral

femur. The inclined plan (i), assigned for ADPPr, belongs to the Previous, Distal, Posterior and Proximal zone femur. A trabecular and cortical solid mesh are also presented.

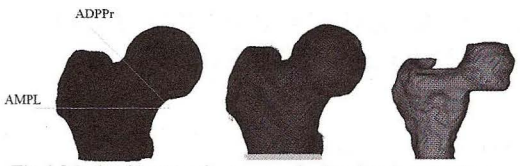

Fig.1 Mesh of human femur: cortical and trabecular bone.

The results of the equivalent stresses in plan (h) and plan (i) are represented in figure 2. In the Medial femur part the stresses are more raised, being that the influence of the mechanical properties if reflects in the Lateral femur zone.

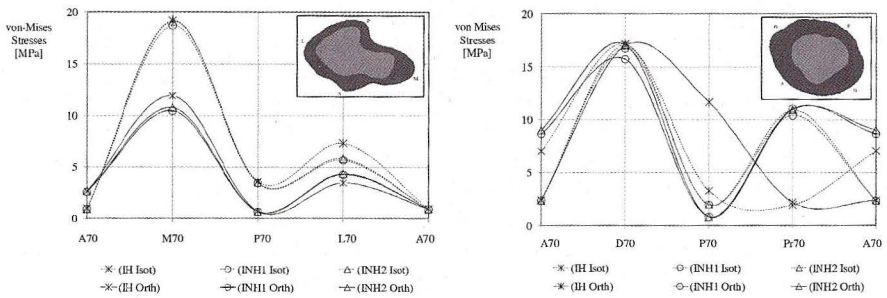

Fig.2 Equivalent stresses in cortical zone (h) and (i).

CONCLUSIONS

The maximum values of stresses in compression were observed in the Medial and Distal zones. The influence of mechanical properties, due different bone density, modifies the numerical results significantly. The values of stresses are lesser in the Posterior zone of femur. The relevance of the mechanical properties use under bone density influence is a greater importance in this study. The results obtained with orthotropic materials, were lesser than when using isotropic properties.

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