EXPERIMENTAL MECHANICS
New Trends and Perspectives

J.F. Silva Gomes, Mário A.P. Vaz
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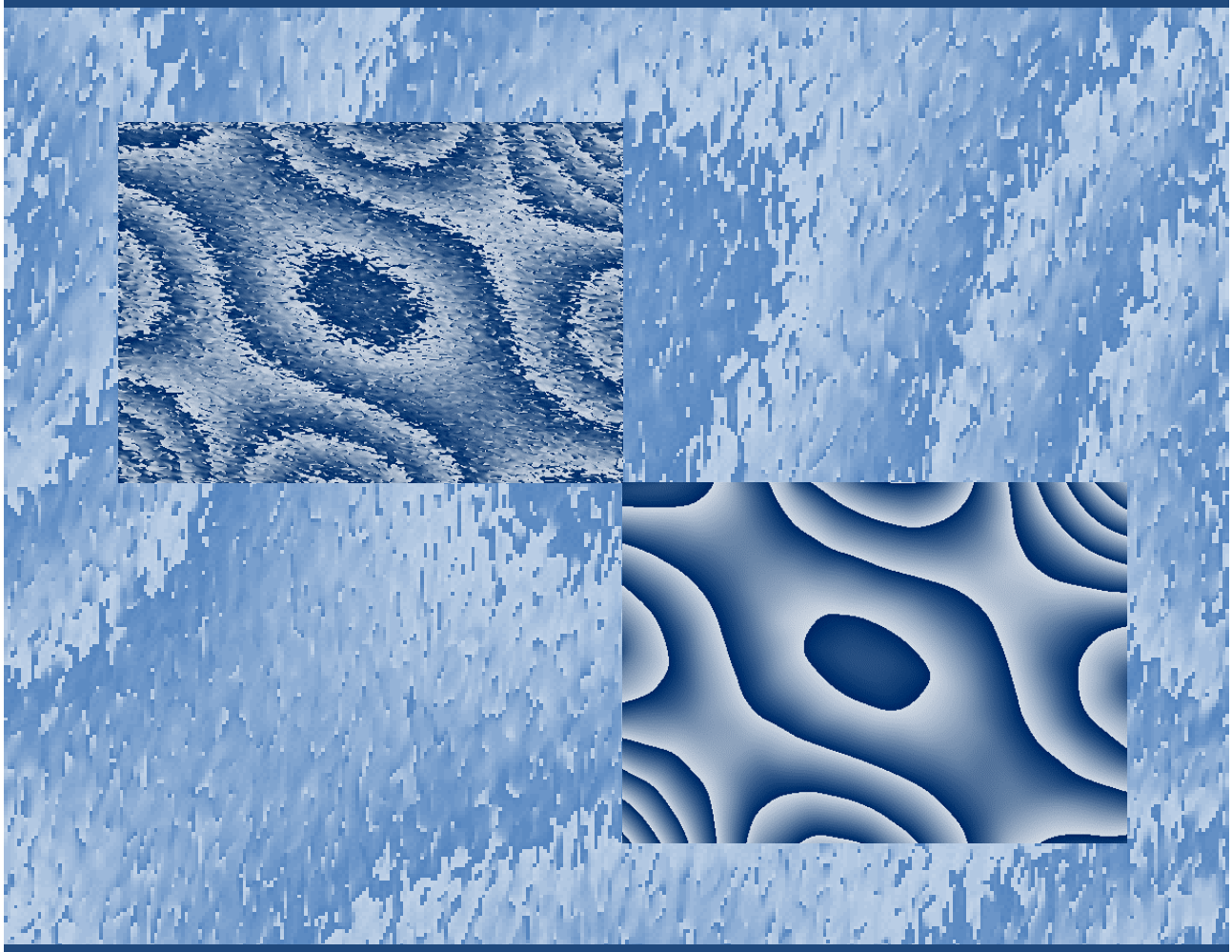

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(NEW TRENDS AND PERSPECTIVES)

J.F. Silva Gomes, Mário A.P. Vaz (Ed)

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PREFACE

Engineering practice in general and mechanical design in particular are basically exercises of creativity, triggered by specific needs. As the engineering community continues to cross the boundaries of known practices, design and manufacturing techniques into the frontiers of new materials and mechanical systems, energy sources and their effects upon the environment, the opportunities for failure will inevitably increase. If our knowledge of how to engineer systems, structures and components to minimize or prevent failure is to keep pace with modern demanding applications and the intolerance of a safety conscious society, we must develop and apply superior analytical and experimental tools to evaluate the potential for damage or failure of engineering structures and/or components and the associated energy harvesting systems.

Different tools are available to optimize any engineering solution, from which *Experimental Mechanics* has always played a most prominent role. It is related to such diverse disciplines as physical and mechanical sciences, engineering (mechanical, aeronautical, civil, automotive, nuclear, etc.), materials, electronics, medicine and biology, and uses experimental methodologies to test and evaluate the behaviour and performance of all kinds of materials, structures and mechanical systems. Quality control, safety, destructive and non-destructive testing of materials and components, analysis of prototypes and even fundamental research are some of the possible applications of *Experimental Mechanics*. During the last few decades the development of computer based techniques, as well as laser-optics methods, nanotechnologies and nanomaterials, among many other technological advances, added new dimensions and perspectives to *Experimental Mechanics and Testing*.

This volume contains the extended Abstracts of the 564 papers accepted for presentation in the ICEM15-15th International Conference on Experimental Mechanics held in Porto/Portugal, 22-27 July 2012. It is complemented by an accompanying CD-ROM containing the full length text of the papers. The book is organized in three main parts: PART-A, with the abstracts of the 11 Invited Plenary Papers, by distinguished academics and scientists in the field of *Experimental Mechanics*; PART-B, with 289 abstracts distributed by the 12 general main topics (from A to L); and PART-C, with the remaining 264 abstracts from the 20 Special Symposia in ICEM15.

The ICEM15 conference is part of a prestigious series of conferences that was initiated in 1959, in Delft (The Netherlands), and the last one took place in Poitiers (France) in July 2010. All these *Experimental Mechanics* meetings resulted from the belief that of those disciplines associated with advanced product design and manufacture, experimental mechanics techniques have been making continuous and significant advances during the years. Important and dramatic improvements in systems and components design can be made by the use of the latest advances in experimental mechanics techniques applied to energy systems, structures and materials. Their effect on the environment is significant and will help in avoiding global warming and harmful CO_2 emissions.

It is organized by the Faculty of Engineering of the University of Porto (FEUP) and the Portuguese Association for Experimental Mechanics (APAET), under the auspices of the European Association for Experimental Mechanics (EURASEM), and sponsored by a number of national and international organizations, whose support is gratefully acknowledged: SEM-

American Society for Experimental Mechanics, BSSM-British Society for Strain Measurement, JSME-Japanese Society of Mechanical Engineering, IMEKO-International Measurement Confederation, AFM-Association Française de Mécanique, DYMAT-European Association for Dynamics of Materials, INEGI-Instituto de Engenharia Mecânica e Gestão Industrial, LABIOMEP-Laboratório de Biomecânica do Porto, LNEC-Laboratório Nacional de Engenharia Civil, FCT-Fundação para a Ciência e a Tecnologia, FCG-Fundação Calouste Gulbenkian, FLAD-Fundação Luso-Americana para o Desenvolvimento, CCDRN-Comissão de Coordenação e Desenvolvimento Regional do Norte, ABEU-PCO, Professional Congress Organizer, and Teatro Nacional S. João/Secretaria de Estado da Cultura.

We are particularly indebted to all *Symposium Promoters* for the coordination of the different themes and to the authors for their papers and presentations. The different contributions during the conference offered opportunities for thorough discussions with the authors. We acknowledge all of the participants, who contributed with innovations, new research approaches, novel techniques and testing methodologies, and their invaluable critical comments.

We are also indebted to the eleven outstanding *Plenary Lecturers* who highlighted the conference themes with their contributions: Dr. Shaker A. Meguid (University of Toronto/Canada), Dr. Gustavo B. Guimarães (Manufacture Engineering, EMBRAER/Brazil), Dr. Yoshiharu Morimoto (Moire Institute Inc., and Wakayama University, Wakayama, Japan), Dr. Emmanuel Gdoutos (Democritus University of Thrace, Greece), Dr. Robert A.W. Mines (University of Liverpool, United Kingdom), Dr. Sergei T. Mileiko (Russian Academy of Sciences, Russia), Dr. Michael B. Prime ((Los Alamos National Laboratory, USA), Dr. Mário A.P. Vaz (University of Porto, Portugal), Dr. Josef Eberhardsteiner (Vienna University of Technology, Austria), Dr. José Ygnacio Pastor (Technical University of Madrid, Spain), and Dr. Alfredo L. Campos (LNEC, Portugal).

Finally, we wish to express our gratitude to the members of the International Scientific Committee for reviewing the papers and the Proceedings, and to the members of the Local Conference Organizing Committee: António T. Marques, Paulo T. de Castro, A.J.M. Ferreira, Carlos C. António, Jorge Seabra, J.D. Rodrigues, Clito F. Afonso, Álvaro Cunha, Elsa Caetano, and Rui C. Barros, and the National Organizing Committee: João Ferreira (IST, Lisbon), Jorge Gomes (LNEC, Lisbon), José M. Cirne (UC, Coimbra), Paulo G. Piloto (IPB, Bragança), Mário Santos (LNEG, Lisbon).

J.F. Silva Gomes and Mário A.P. Vaz

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Biomedical Applications and 3D Rapid Prototyping

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PAPER REF: 2711

EVALUATION OF THE CORTICAL BONE THICKNESS IN LUMBAR VERTEBRA USING CT AND RP EXPERIMENTAL TECHNIQUES

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ABSTRACT

The main objective of this paper was to assess the cortical bone thickness of human lumbar vertebra, through Computed Tomography (CT) images by using both image processing software and rapid prototyping (RP) experimental methodologies. The study here presented focus sixteen postmenopausal patients from the North of Portugal, with age between 50 and 85 years, collected from May to June 2011. All clinical data were obtained in a Medical Centre of Radiology and Imaging, in Porto. Results regarding cortical bone thickness and biomechanical resistance of human lumbar vertebra are presented. The acquirement of accurate values concerning cortical bone thickness could improve the prediction of fracture risk.

INTRODUCTION

Bone Mass Density (BMD) is a good predictor of fractures, particularly at the spine (Beaupied 2007). Nonetheless, fracture risk assessment based only on trabecular BMD, disregards other features of bone's biomechanical competence. Age-related physical changes include decreased cortical thickness, one of several structural changes that translate to alterations in bone's strength and risk for fracture (Epstein S, 2006). Thus, consideration of cortical bone thickness clearly improves the prediction of fracture risk. CT is the most common technique used for examination in medicine, because it permits the visualization of soft tissues and bone structures (Cavalcanti, 2001). Actually, CT images can be processed using specific software that allows analysing the bone geometry and creating 3D templates of anatomical specimens.

RESULTS AND CONCLUSIONS

The current study was based on spine CT images and previous results from BMD exams. Women were previous classified according to BMD score, as a normal, osteopenic and osteoporotic. The cortical thickness in the body of the lumbar vertebra (L2-L5) was evaluated using two methodologies. First, the cortical thickness was measured in different layers, through 5 anatomical positions, using image processing software (iQ-VIEW). The 3D visualization of the medical images was obtained using InVesalius 3.0 (FREE Beta2 Software, C.T.I. Renato Archer). Fig. 1 represents a CT and all different anatomical positions considered for this study. Second, an experimental technique RP was used to measure the cortical thickness in different body of lumbar vertebra. This method was originally introduced in industry to improve design and reduce product development time, now being applied to medicine, allowing an immediate and intuitive understanding of the most complex 3D geometry (McGurk, 1997). Each segment of lumbar vertebra was produced with a monochromatic 3D ZPrinter from digital data using RP experimental technology. Using this

technique the cortical bone thickness will be measured and compared with the values previous obtained. Fig. 2 shows the experimental RP procedure used for measuring some different lumbar vertebra slices of a female patient with 52 years (F52).

Fig. 1 - CT obtained in medical clinical to measure the cortical lumbar vertebra (L2-L5).

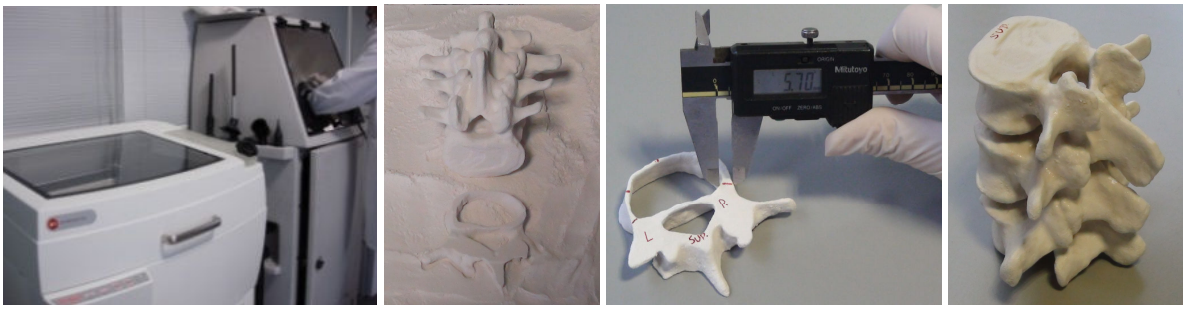

Fig. 2 - ZPrinter and RP experimental methodology used for measure lumbar vertebra segments L4-L2, F52.

The distribution of participants according to the age range and BMD score is presented in Table 1, with the identification of the pathology in lumbar vertebral L4. The values of cortical thickness in L4 from F52 are shown in Table 2.

Table 1 - BMD score in lumbar vertebra L4.

	Women's age (years) n (%)		
	50-59	60-69	>70
Normal	2 (40.0)	1 (11.0)	1 (50.0)
Osteopenic	2 (40.0)	5 (56.0)	0 (0.0)
Osteoporotic	1 (20.0)	3 (33.0)	1 (50.0)

Table 2 - Cortical thickness with RP and iQ-VIEW.

Position in L4:	1	2	3	4	5
RP [cm]	0.4	0.2	0.2	0.4	0.5
iQ-VIEW [cm]	0.3	0.2	0.2	0.4	0.4

The use of CT and RP experimental methodologies gave results quite similar regarding the cortical thickness. Further analysis will provide this information for all patients, according to the age range and the previous diagnosis of osteopenia or osteoporosis. The use of this information could be useful for complementary diagnostic and clinical treatment planning.

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