J.F. Silva Gomes
Shaker A. Meguid
Editors

RECENT ADVANCES IN MECHANICS AND MATERIALS IN DESIGN

Proceedings of the 6th International Conference on Mechanics and Materials in Design, P. Delgada, Portugal, 26-30 July 2015

FEUP-INEGI
(2015)

About the Book:

During the last few decades the development of computer based techniques, as well as new experimental methods, nanotechnologies and nanomaterials, among many other material technological advances, added new dimension and perspectives to mechanical design and manufacturing of engineering systems, structures and components. Different tools are now available to optimize any engineering solution, and we must continue our efforts to develop and use superior materials, apply reliable analytical and numerical techniques and validate these with sound experimental methods.

This volume contains the extended Abstracts of papers accepted for presentation in the *M2D2015 - 6th International Conference on Mechanics and Materials in Design* held in Ponta Delgada/Portugal, 26-30 July 2015. The book is complemented by an accompanying CD-ROM containing the full length papers.

M2D2015 is part of a prestigious series of conferences that was initiated in 1996, in Toronto (Canada), coordinated by the International Scientific Committee on Mechanics and Materials in Design. The conference attracted over 320 participants with 423 accepted submissions from 42 different countries around the world. These papers were presented in July 26-30, 2015 in the magnificent city of Ponta Delgada-Azores, Portugal. The conference themes, which address novel and advanced topics in Mechanics and Materials in Design, focused on analytical and numerical tools at all scales, testing and diagnostics, surface and interface engineering, tribology, mechanical design and prototyping, modes of failure, composite and engineered materials, biomechanics, energy and thermo-fluid systems, impact and crashworthiness and case studies.

ISBN: 978-989-98832-2-2

M2D2015

RECENT ADVANCES IN
MECHANICS AND MATERIALS IN DESIGN

Editors

J.F. Silva Gomes and Shaker A. Meguid

ISBN: 978-989-98832-2-2
(2015)

Distribution

ABREU PCO - PORTO
Av. dos Aliados, 207, 4000-067 Porto - Portugal
Telefone: +351 22 2043570 Email: pcoportugal@abreu.pt
http://pco.abreu.pt/Default.aspx

July, 2015

ISBN: 978-989-98832-2-2
Legal Deposit No: 389985/15

Printed by:

LusoImpress S.A.
Rua Venceslau Ramos, 28 - 4430-929 Avintes, Portugal
Tel:+351 22 787 73 20; Fax:+351 22 787 73 29
www.lusoimpress.com

Cover design by J.F. Silva Gomes (INEGI/FEUP)

TABLE OF CONTENTS

EDITORS' PREFACE

M2D2015 is the sixth international gathering of a prestigious series of conferences coordinated by the International Scientific Committee of Mechanics and Materials in Design. This series of conferences are wholy devoted to advances in mechanics, materials, structural integrity and design. M2D2015 is sponsored by the University of Porto, the University of Toronto and the University of Azores. The conference attracted over 320 participants with 423 accepted submissions from 42 countries out of 620 submissions. These papers were presented in July 26-30, 2015 in the magnificent city of Ponta Delgada, Azores. The conference themes which address novel and advanced topics in Mechanics and Materials in Design focused on analytical and numerical tools at all scales, testing and diagnostics, surface and interface engineering, tribology, mechanical design and prototyping, modes of failure, composite and engineered materials, biomechanics, energy and thermo-fluid systems, impact and crashworthiness and case studies.

We believe that the meeting offered our delegates a forum for the dissemination of their recent work in mechanics and materials and their applications in engineering design, fostered research that integrates mechanics and materials in the design process, and promoted exchange of ideas and international co-operation among scientists and engineers in this important field of engineering.

We are particularly indebted to the authors and special guests for their presentations. Each of the more than 420 contributions offered opportunities for thorough discussions with the authors. Particularly, we acknowledge the excellent contributions of the participants, their innovative ideas and research directions, the novel modeling and simulation techniques, and the invaluable critical comments. We are also indebted to the outstanding keynote speakers who highlighted the conference themes with their contributions and covered the main topics of the conference. We also take this opportunity to thank the members of the International Scientific Committee and the reviewers for their time, effort and helpful suggestions.

We offer our sincere gratitude to the symposia organisers for their efforts and valuable contributions to the success of the event, and the local organising committee for attending to the conference demands and delegates needs.

All in all, M2D2015 was a great success and the credit must go to all the participants for their significant contributions and lively discussions, the keynote speakers for bridging the gap between the different disciplines and the organizing committee for an absolutely superb organization of the meeting in this magnificent city. To all of you, we offer our gratitude.

Given the rapidity with which science is advancing in all areas of mechanics and materials, the next conference in this series (Integrity, Reliability and Failure - IRF 2016) will take place in Porto, Portugal in July 2016. Undoubtedly, we expect IRF2016 to be as stimulating and interesting as M2D2015, as evidenced by the excellent contributions offered in this current event. We look forward to seeing all of you in Porto in 2016.

Shaker A. Meguid and J.F. Silva Gomes
P. Delgada / Azores, July 2015

International Scientific Committee

Aben, H. (Estonia)
Abreu, M.J. (Portugal)
Adali, S. (S. Africa)
Afonso, C.F. (Portugal)
Alexopoulos, N. (Greece)
Alves, A. (Portugal)
António, C.C. (Portugal)
Arêde, A. (Portugal)
Banks-Sills, L. (Israel)
Baptista, J.S. (Portugal)
Barradas, J. (Portugal)
Barros, M.J. (Portugal)
Barros, R.C. (Portugal)
Belinha, J. (Portugal)
Botsis, J. (Switzerland)
Bremand, F. (France)
Caetano, E. (Portugal)
Camanho, P. (Portugal)
Campos, J.R. (Portugal)
Castro, C.F. (Portugal)
Castro, P.T. (Portugal)
Catarino, A. (Portugal)
Cavaleiro, A. (Portugal)
Chen, T. (Taiwan)
Chenot, J-L (France)
Cirne, J. (Portugal)
Correia, A. (Portugal)
Croccolo, D. (Italy)
Cunha, A. (Portugal)
Datta, S. (USA)
Degrieck, J. (Belgium)
Dias, G. (Portugal)
Dietrich, L. (Poland)
Diogo, M.T. (Portugal)
Dourado, N. (Portugal)
Eberhardsteiner, J. (Austria)
Esteves, J.L. (Portugal)
Fangueiro, R. (Portugal)
Fernandes, A.A. (Portugal)
Ferreira, D. (Portugal)
Ferreira, J.G. (Portugal)
Fiúza, A. (Portugal)
Fonseca E. (Portugal)
Gdoutos, E. (Greece)
Geraldes, M. (Portugal
Guedes, R.M. (Portugal)
Hejum, Du (Singapore)
Igartua, A. (Spain)
Ignaszak, Z. (Poland)
Iliescu, N. (Romania)
Jones, N. (UK)
Jorge, R.N. (Portugal)
Kahlen, F-J. (S. Africa)
Klein, W. (Germany)
Kourkoulis, S. (Greece)
Laermann, K. (Germany)
Langseth, M. (Norway)
Lima, G. (Brazil)
Lino, J. (Portugal)
Lopes, H. (Portugal)
Lu, Jian (Hong Kong)
Madureira, L. (Portugal)
Maia, Lino (Portugal)
Mal, A. (USA)
Marques, A.T. (Portugal)
Martins, R. (Portugal)
Masato, Y. (Japan)
Meda, A. (Italy)
Meguid, S.A. (Canada)
Melo, F.Q. (Portugal)
Mileiko, S.T. (Russia)
Miller, R.E. (Canada)
Mines, R. (UK)
Miranda, R. (Portugal)
Moreira, F. (Portugal)
Moreira, P. (Portugal)
Morimoto, Y. (Japan)
Moura, M.F. (Portugal)
Muc, Aleksander (Poland)
Navarro, C. (Spain)
Navas, H. (Portugal)
Pappalettere, C. (Italy)
Pieczyska, E. (Poland)
Piloto, P. (Portugal)
Pindera, M.J. (USA)
Polcar, T. (UK)
Quelhas, O. (Brazil)
Ramesh, K. (India)
Reddy, J.N. (USA)
Restivo, M.T. (Portugal)
Ribeiro, J.E. (Portugal)
Robinson, J. (Ireland)
Rocha, A.B. (Portugal)
Rodrigues, H. (Portugal)
Rodrigues, J.D. (Portugal)
Roque, Carla (Portugal)
Ruiz, G. (Spain)
Ruzicka, M. (Czech R.)
Sá, Carlos (Portugal)
Sainov, V. (Bulgaria)
Santos, J.M. (Portugal)
Santos, T. (Portugal)
Seabra, J. (Portugal)
Semenski, D. (Croatia)
Silva, A.J. (Portugal)
Silva, Lucas (Portugal)
Silva Gomes, J.F. (Portugal)
Sjödahl, M. (Sweden)
Soares, C.M. (Portugal)
Sousa, L.C. (Portugal)
Sousa, R. (Portugal)
Su, Yu (China)
Suleman, Afzal (Portugal)
Takagi, T. (Japan)
Talaia, M. (Portugal)
Tamalsky, E. (Brazil)
Tamuzs, V. (Latvia)
Tavares, J.M. (Portugal)
Tavares, P. (Portugal)
Tooren, M.J. (Netherlands)
Truman, C.E. (UK)
Turmanidze, R. (Georgia)
VanHemelrijck, D. (Belgium)
Varum, H. (Portugal)
Vasques, C. (Portugal)
Vaz, Mário P. (Portugal)
Vilas-Boas, J. (Portugal)
Wang, Wei-Chung (Taiwan)
Weng, G. (USA)
Yoneyama, Satoru (Japan)
Yoon, Y.C. (Singapore)
Zhang, X. (China)

Institutional Sponsors

FEUP
University of Porto
Portugal

MADL
University of Toronto
Canada

DCTD
University of Azores
Portugal

Co-Chairs

J.F. Silva Gomes (*U. Porto)*

Shaker A. Meguid (*U. Toronto*)

Organizing Committee

Carlos C. António, Catarina F. Castro, Clito F. Afonso, José M. Cirne
Maria João Barros, Mário A.P. Vaz, Paulo G. Piloto, Pedro M.G.P. Moreira

Conference Secretariat

Nuno Pinto, Lurdes Catalino, M.F. Silva Gomes

With the support of

ABREU-PCO, Professional Congress Organizer (http://pco.abreu.pt)
Mercatura Conference System (http://www.mercatura.pt)

TRACKS / MAIN TOPICS:

Topic - A: Analytical and Numerical Tools
Topic - B: Testing and Diagnostics
Topic - C: Surface and Interface Engineering
Topic - D: Civil Engineering Applications
Topic - F: Tribology, Gears and Transmissions
Topic - G: Mechanical Design and Prototyping
Topic - H: Modes of Failure
Topic - I: Composite and Advanced Materials
Topic - J: Nanotechnologies and Nanomaterials
Topic - K: Biomechanical Applications
Topic - L: Energy and Thermo - Fluids Systems
Topic - M: Impact and Crashworthiness
Topic - N: Case Studies

SPECIAL SYMPOSIA:

Symp - 2: EXPERIMENTAL MECHANICS IN DESIGN.
Coordinators: Hernani Lopes (ISEP/IPP, Portugal) and Jaime Monteiro (INEGI/U.Porto, Portugal)

Symp - 3: DYNAMICS, STABILITY AND CONTROL IN STRUCTURAL ENGINEERING: CASE STUDIES.
Coordinator: Rui C. Barros (FEUP/U. Porto, Portugal)

Symp - 4: ANALYSIS DESIGN AND TESTING OF TOWERS AND POLES.
Coordinator: Rui C. Barros (FEUP/U. Porto, Portugal)

Symp - 5: DESIGN AND PRODUCT DEVELOPMENT.
Coordinators: Jorge Lino (FEUP/U. Porto, Portugal) and Xavier de Carvalho (FEUP/U.Porto, Portugal)

Symp - 6: MECHANICAL BEHAVIOUR OF BIO-BASED MATERIALS.
Coordinators: Nuno Dourado (CITAB/UTAD, Portugal) and Marcelo Moura (FEUP/U. Porto, Portugal)

Symp - 9: SYSTEMATIC INNOVATION AND LEAN APPROACH IN ENGINEERING.
Coordinators: Helena V.G. Navas (FCT/UNL, Portugal) and Anabela Alves (U. Minho, Portugal)

Symp - 10: SEISMIC BEHAVIOUR CHARACTERIZATION AND STRENGTHENING OF CONSTRUCTIONS.
Coordinators: António Arêde (FEUP/U. Porto, Portugal), Humberto Varum (FEUP/U. Porto, Portugal), Hugo Rodrigues (ESTG/IPL, Portugal) and Aníbal Costa (DECivil/U. Aveiro, Portugal)

Symp - 11: MECHANICS AND MATERIALS IN DENTAL MEDICINE.
Coordinators: J.C. Reis Campos (FMD/U. Porto, Portugal) and Mário A.P. Vaz (FEUP/U. Porto, Portugal)

Symp - 12: OPTIMIZATION FOR SUSTAINABLE DEVELOPMENT.
Coordinators: Carlos C. António (FEUP/U. Porto, Portugal) and Catarina F. Castro (FEUP/U. Porto, Portugal)

Symp - 13: CARDIOVASCULAR AND ORTHOPEDIC MECHANICS DESIGN.
Coordinators: Luísa C. Sousa (FEUP/U. Porto, Portugal) and Catarina F. Castro (FEUP/U. Porto, Portugal)

Symp - 17: MECHANICAL BEHAVIORS OF ADVANCED MATERIALS & STRUCTURES AT ALL SCALES.
Coordinator: Yu Su (Beijing Institute of Technology, China)

Symp - 18: MECHANICAL BEHAVIOR OF SOFT BIOMATERIALS.
Coordinators: Renato N. Jorge (FEUP/U.Porto, Portugal), Pedro Martins (FEUP/U.Porto, Portugal) and Marco Parente (FEUP/U.Porto, Portugal)

Symp - 19: NON-DESTRUCTIVE INSPECTION TECHNIQUES FOR MATERIALS AND STRUCTURES.
Coordinators: João Tavares (FEUP/U.Porto, Portugal), Luís Durão (ISEP/IPP, Portugal) and João Rebello (UFRJ, Brazil)

Symp - 20: THERMAL COMFORT IN BUILDINGS.
Coordinators: Marta Silva (U. Aveiro) and Mário Talaia (U. Aveiro, Portugal)

Symp - 21: TRIBOLOGY TRENDS FOR HIGHER EFFICIENCY AND RELIABILITY.
Coordinators: Ramiro Martins (INEGI/U.Porto, Portugal), Jorge Castro (INEGI/U.Porto, Portugal), Armando Campos (INEGI/U.Porto, Portugal) and Jorge Seabra (INEGI/U.Porto, Portugal)

Symp - 22: RECYCLING AND RE-USE OF INDUSTRIAL AND HOUSEHOLD WASTES INTO NEW COMPOSITE MATERIALS.
Coordinators: A. Fiúza (CIGAR/U.Porto, Portugal) and M.C.S. Ribeiro (INEGI/U.Porto, Portugal)

Symp - 23: QUALITY CONTROL AND METROLOGY IN ENGINEERING.
Coordinators: José Barradas (CATIM, Portugal), José Carlos Sá (IPVC, Portugal) and José Oliveira (IPVC, Portugal)

Symp - 24: THERMODYNAMICS AND FLUIDS.
Coordinator: Clito F. Afonso (FEUP/U.Porto, Portugal)

Symp - 25: COMPUTATIONAL MECHANICS IN DESIGN.
Coordinator: Xiong Zhang (Tsinghua University, China)

Symp - 26: FIBER BASED MATERIALS: DESIGN, DEVELOPMENT AND APPLICATIONS.
Coordinators: Maria José Abreu (U. Minho, Portugal) and André Catarino (U. Minho, Portugal)

Symp - 27: THIN FILMS AND COATINGS IN TRIBOLOGY.
Coordinators: Albano Cavaleiro (FCTUC/U. Coimbra, Portugal) and Tomas Polcar (U. Southampton, U.K.)

Symp - 28: ADVANCED DISCRETIZATION TECHNIQUES IN COMPUTATIONAL MECHANICS.
Coordinators: Jorge Belinha (INEGI/U.Porto, Portugal) and Carla Roque (INEGI/U.Porto, Portugal)

Symp - 29: SAFETY IN WOOD MATERIALS.
Coordinators: Elza Fonseca (IPB, Portugal) and Débora Ferreira (IPB, Portugal)

Symp - 31: FIRE AND STRUCTURAL ENGINEERING.
Coordinators: Paulo Piloto (IPB, Portugal) and Alberto Meda (U. Rome, Italy)

PAPER REF: 5709

COMPOSITE MATERIALS AND BOVINE CORTICAL BONE DRILLING: THERMAL EXPERIMENTAL ANALYSIS

Maria Fernandes[1], Elza Fonseca[2(*)], Renato Natal[1], Mário Vaz[1], Maria Isabel Dias[3]

[1]INEGI, Faculty of Engineering, University of Porto, Porto, Portugal
[2]LAETA-INEGI / UMNMEE Department of Applied Mechanics, Polytechnic Institute of Bragança, Portugal
[3]CITAB, University of Tras-os-Montes e Alto Douro, Vila Real, Portugal
[(*)]*Email:* efonseca@ipb.pt

ABSTRACT

The bone drilling is a common procedure in orthopaedic surgery, mainly in the treatment of fractures and reconstructive surgery. The success of this surgeries is dependent of many factors and also in heat generation control during the drilling bone. The main concern in bone drilling are the mechanical and thermal damage of the bone induced by inappropriate parameters such as drill speed and feed-rate during surgical procedures. This paper studies the problem of generation heat in drilling process of composite materials, with similar mechanical properties to the human bone, and in bovine cortical bone. The main goal was study the evolution of temperature through the different experimental methodologies using different drilling parameters. It was concluded when the drill speed and feed-rate are higher the bone temperature increase is lower. The results of temperature in the drilling process of composite material or bovine bone were compared and were found a good agreement with both.

Keywords: cortical bone, drilling, composite material, bovine cortical bone.

INTRODUCTION

The bone drilling is an essential step in many clinical procedures, such as surgical reconstruction, bone and implant fixation (Li et al., 2014). One of main problems in bone drilling is the heat generation during the drilling process. The increase of heat is caused by friction between the cutting surface of the drill bit in contact with the hole and bone fragments formed during the drilling. When the temperatures obtained during drilling operation reached the limit supported by bone tissue, thermal necrosis can occur (Sezek et al., 2012, Lundskog, 1972). Currently, it is known that the temperature generated in these processes is associated to drilling parameters and is essential to understand and to improve the drilling conditions and all the variables involved to reduce the heat generated and consequently minimize the bone damage.

The main goal of this study was to use different experimental methodologies for analysis and temperature evaluation during the drilling process of cortical composite materials and bovine bone (Figure 1). The effect of some variables related with the drilling process were studied. During the drilling process the temperature was measured using thermocouples and a thermographic camera in composite materials. In bovine cortical bones only the thermographic camera was used to measure the temperature in drill bit and bone surface.

Different drill speed were used in the experimental tests: 600, 800, 1200 rpm; and feed-rates of 25, 50 and 75mm/min. In all experimental tests a drill bit with a diameter equal to 4mm was used.

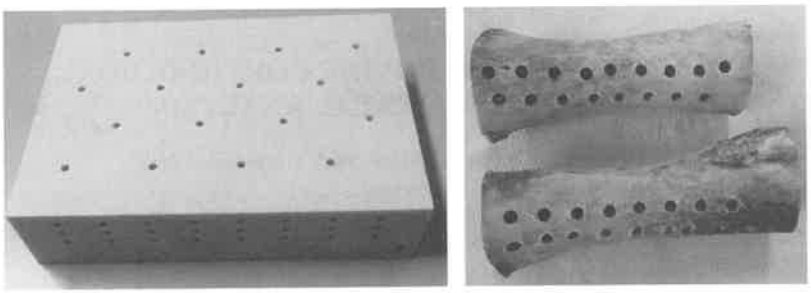

Fig. 1 - Composite material and bovine cortical bone.

RESULTS AND CONCLUSIONS

The present study showed the combinations of different parameters, producing temperatures far below the critical values. It was concluded when the feed-rate and the drill speed are higher the bone temperature increase is lower. The values of temperature in the drilling process of composite material or bovine bones were similar. Therefore the composite materials can supply a good accuracy in predicting the temperature rise during the drilling bone.

ACKNOWLEDGMENTS

The author of this paper acknowledges the support of the Project "Biomechanics: Contributions to the healthcare" co-financed by the Regional Operational Programme of North (ON.2 - The New North), the National Strategic Reference Framework (NSRF), through the European Development Fund (ERDF).

REFERENCES

[1]-Li S, Wahab AA, Demirci E, Silberschmidt VV. Penetration of cutting tool into cortical bone: Experimental and numerical investigation of anisotropic mechanical behaviour. J Biomech, 2014, 47, p.1117-1126.

[2]-Sezek S, Aksakal B, Karaca F. Influence of drill parameters on bone temperature and necrosis: A FEM modelling and in vitro experiments. Computational Materials Science, 2012, 60, p.13-18.

[3]-Lundskog J. Heat and bone tissue. An experimental investigation of the thermal properties of bone and threshold levels from thermal injury. Scand J Plast Reconstr Surg, 1972, 6, p.5-75.