IRF2016

NEW TRENDS ON
INTEGRITY-RELIABILITY FAILURE

Editors

J.F. Silva Gomes and Shaker A. Meguid

FEUP-INEGI
(2016)

Published by

INEGI-Instituto de Ciência e Inovação em Engenharia Mecânica e Gestão Industrial
Rua Dr Roberto Frias, 4200-465 Porto - Portugal
Telefone: +351 22 9578710; Email: inegi@inegi.up.pt
http://www.inegi.up.pt/

July, 2016

ISBN: 978-989-98832-4-6
N. DL: 407176/16

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

TABLE OF CONTENTS

International Scientific Committee

Aben, H. (Estonia)
Adali, S. (S. Africa)
Afonso, C.F. (Portugal)
Alexopoulos, N. (Greece)
António, C.C. (Portugal)
Banks-Sills, L. (Israel)
Baptista, J.S. (Portugal)
Barros, R.C. (Portugal)
Bathe, K.J. (USA)
Botsis, J. (Switzerland)
Braz-César, M. (Portugal)
Caetano, E. (Portugal)
Camanho, P. (Portugal)
Campos, J.R. (Portugal)
Campos, Vicente (Portugal)
Castro, C.F. (Portugal)
Castro, P.T. (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)
Dietrich, L. (Poland)
Eberhardsteiner, J. (Austria)
Fernandes, A.A. (Portugal)
Ferreira, D. (Portugal)
Ferreira, J.G. (Portugal)
Fiúza, A. (Portugal)
Fonseca E. (Portugal)
Gdoutos, E. (Greece)
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)
Mal, A. (USA)
Marques, A.T. (Portugal)
Masato, Y. (Japan)
Meda, A. (Italy)
Meguid, S.A. (Canada)
Mileiko, S.T. (Russia)
Miller, R.E. (Canada)
Mines, R. (UK)
Moreira, P. (Portugal)
Morimoto, Y. (Japan)
Moura, M.F. (Portugal)
Muc, Aleksander (Poland)
Noroozinejad, E. (Iran)
Pappalettere, C. (Italy)
Pieczyska, E. (Poland)
Piloto, P. (Portugal)
Pindera, M.J. (USA)
Quelhas, O. (Brazil)
Ramesh, K. (India)
Reddy, J.N. (USA)
Robinson, J. (Ireland)
Ruiz, G. (Spain)
Ruzicka, M. (Czech R.)
Sainov, V. (Bulgaria)
Seabra, Jorge (Portugal)
Semenski, D. (Croatia)
Silva Gomes, J.F. (Portugal)
Sjödahl, M. (Sweden)
Sousa, L.C. (Portugal
Takagi, T. (Japan)
Tamalsky, E. (Brazil)
Tamuzs, V. (Latvia)
Tavares, J.M. (Portugal)
Tavares, P. (Portugal)
Tooren, M.J. (Netherlands)
Truman, C.E. (UK)
Turmanidze, R. (Georgia)
Umehara, N. (Japan)
VanHemelrijck, D. (Belgium)
Varum, H. (Portugal)
Vaz, Mário P. (Portugal)
Wang, Wei-Chung (Taiwan)
Weng, G. (USA)
Yang, Fan (China)
Yoneyama, Satoru (Japan)
Yong, N.T. (Singapore)
Yoon, Y.C. (Singapore)
Zhang, Z. (China)

Institutional Sponsors

FEUP
University of Porto
Portugal

MADL
University of Toronto
Canada

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
Mário A.P. Vaz, Paulo G. Piloto, Pedro M.G.P. Moreira

Conference Secretariat

Nuno Pinto, Lurdes Catalino

With the support of

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

PAPER REF: 6356

INFLUENCE OF BONE DRILLING PARAMETERS ON THE THERMAL STRESS DISTRIBUTION

Maria G. Fernandes[1], Elza M. Fonseca[2(*)], Renato N. Jorge[3]

[1]INEGI, Faculty of Engineering, University of Porto, Portugal
[2]LAETA, INEGI, UMNMEE, Department of Applied Mechanics, Polytechnic Institute of Bragança, Portugal
[3]LAETA, INEGI, Department of Mechanical Engineering, Faculty of Engineering, University of Porto, Portugal
[(*)]*Email:* efonseca@ipb.pt

ABSTRACT

Material removal through the drilling involves two important processes. The first one is drilling of material by cutting edges of the drill bit and the second one is the friction generated by the contact between drill bit and hole wall of the material. Both processes lead to heat generation during drilling. In clinical practice, drilling procedures and high-speed cutting tools are often applied on bone tissue. These operations are associated to complications such as thermal osteonecrosis due to the excessive heat generation and mechanical damage due to the excessive levels of penetration force. The development of additional tools for accurately simulating the drilling is essential to predict the risk of thermo-mechanical damage during bone drilling. This paper investigates the thermal and mechanical damage in bone tissue induced by different parameters. An experimental and numerical approach of bone drilling has been conducted. A three-dimensional dynamic numerical model was developed to simulate the mechanical and thermal stresses generated during the drilling. The numerical model incorporates the geometrical and dynamic characteristics involved in the drilling processes. The numerical analysis has been validated by experimental tests using polyurethane foam materials with similar mechanical properties to the human bone.

Keywords: Bone drilling, damage, experimental testing, numerical modelling.

INTRODUCTION

Drilling is one of the most frequent conventional mechanical processes in machining operations. The industrial concepts of productivity and surface integrity in material removal processes can be translated to medical applications. In this context, reduced drilling time is related to short surgery global time and bone integrity is related to the absence of drilling induced damage (Marco el al. 2015). The common problems associated with the drilling are thermal and mechanical damage due the excessive heat and the cut effort achieved during the process, (Augustin et al. 2008; Fernandes et al. 2015).

Clinical problems such as implant failures have been reported on the literature and are associated with the thermal and mechanical damage which occur during the drilling (Agustin et al. 2008). The importance of this problems have motivated the development of different methodologies. However, it is difficult to draw definitive conclusions due to the wide variety of involved parameters, such as the tool geometry and drilling parameters.

The development of accurate numerical models can help in the understanding of bone drilling and thus in the analysis and definition of drilling operations in bone tissues.

This study presents a three-dimensional dynamic thermomechanical model to simulate the thermal stresses during bone drilling. The numerical model was validated with experimental tests performed on polyurethane foam materials instrumented with strain gauges to measure the strains and thermocouples to measure the temperature distribution inside the blocks (Figure 1). Also, the temperatures on the drill bit and block surfaces were measured with a thermal camera. The effects of some drilling parameters, such as drill speed and feed-rate were studied.

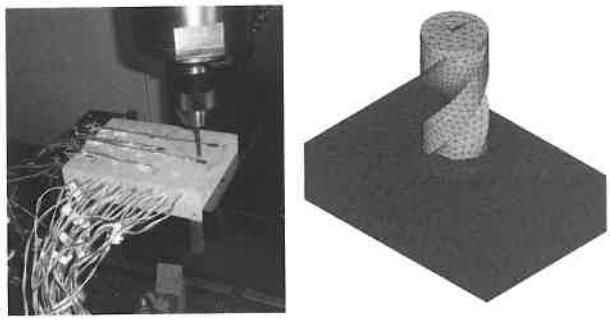

Fig. 1 - Experimental and numerical model of bone drilling.

RESULTS AND CONCLUSIONS

A three-dimensional elastic plastic dynamic model to simulate the drill bit penetration into the bone tissue was developed. Thermal stresses involved in the drilling processes were obtained and compared with experimental tests. The results show that thermal stresses generated in the material tend to increase with tool penetration. The numerical results are in good agreement with experimental results. The proposed numerical model can be used to simulate the behaviour bone during the drilling process, considering different parameters.

ACKNOWLEDGMENTS

This research was supported by the Portuguese Foundation of Science and Technology under research project UID/EMS/50022/2013.

REFERENCES

[1]-Marco M, Rodríguez-Millán M, Santiuste C, Giner E, Minguélez MH. A review on recent advances in numerical modelling of bone cutting. Journal of the Mechanical Behavior of Biomedical Materials, 2015, 44, pp.179-201.

[2]-Fernandes MG, Fonseca EMM, Natal R. Three-dimensional dynamic finite element and experimental models for drilling processes. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, 2015, 0, pp.1-9.

[3]-Augustin G, Davila S, Mihoci K, Udiljak T, Vedrina DS, Antabak A. Thermal osteonecrosis and bone drilling parameters revisited. Archives Orthopaedic and Trauma Surgery, 2008, 128, pp. 71-77.