J.F. Silva Gomes
Shaker A. Meguid
Editors

M2D2015

Proceedings of the 6th International Conference on Mechanics and Materials in Design

P. Delgada (Azores), Portugal, 26-30 July 2015

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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

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IMEKO-International Measurement Confederation
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INEGI-Instituto de Ciência e Inovação em Engª. Mecânica e Engª. Industrial
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NUMERICAL AND EXPERIMENTAL ASSESSEMENT OF THE DISPLACEMENT FIELD ON PDMS SAMPLE

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ABSTRACT

In recent years, the study of polymers like polydimethylsiloxane materials (PDMS) has become a great interest field due its growing used in biomechanics applications. In this work the Digital Image Correlation (DIC) is proposed for the measurement of the continuous displacement field. This experimental optical technique allows the measurement with high resolution and without contact of the large displacements at the material surface and, therefore, is considered the most suitable technique for the mechanical characterization of hyper-elastic materials. The numerical simulations were implemented by using the commercial finite elements program Ansys®. This combines the experimental information taken from the tensile test performed in PDMS with material constitutive models to reproduce the experimental displacement fields observed during the experimental test. For this study, different constitutive hyper-elastic material models were analysed, namely: the Mooney-Rivlin model, Ogden model and Yeoh models.

The numerical technique show to be very effective to reproduced the global mechanical behaviour of hyper-elastic materials. However, the local behaviour is very difficult to predict and further developments must be made in order to improve the quality of material behaviour.

Keywords: polydimethylsiloxane, hyper-elasticity, digital image correlation, biaxial tensile test, finite element method.

INTRODUCTION

In recent decades, the characterization of biological tissues (Greenleaf, 2003) had an enormous evolution. Biomedical Engineering has been at the vanguard in the biological tissues study as well as in the development of new materials for the replacement of these tissues in extreme situations, when other therapies are not possible or not recommended. The soft tissue belongs to the class of materials that have hyper-elastic mechanical behaviour. They are known for presenting high strains before reaching tensile strength (Holzapfel, 2000). Its stress-strain relationship can be derived from a function of strain energy density (Besson, 2010). This stress-strain relationship is reversible and may have linear or nonlinear relationships.

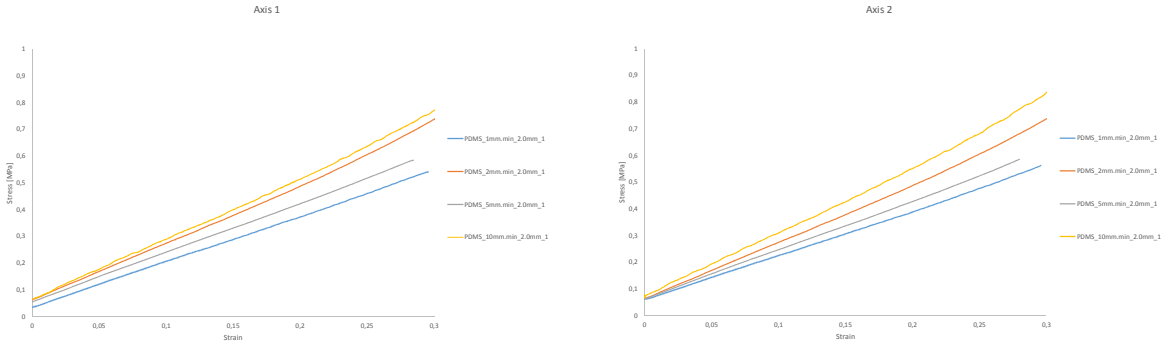
The aim of this work is development of a method that is able to characterize with high detail the mechanical behaviour of PDMS materials used in bioengineering and biological applications. For this purpose, the biaxial tensile test is performed and the full field displacement and strain are measured using DIC technique. From the displacements fields we

assess the most appropriate constitutive models of hyper-elastic materials that could use simulate the mechanical behaviour of the PDMS.

RESULTS AND CONCLUSIONS

The results from the biaxial tensile tests are shown in Fig. 1. These curves were used in the numerical simulations for the constants determination of constitutive model. This information was combined with the displacement measured with the commercial DIC system (Aramis®) for computing the strain fields.

The experimental and the numerical strains were compered and determined the mean relative error, presented in Table 1.



(a) (b)

Fig. 1 - Biaxial tensile test results in: (a) axis 1 and (b) axis 2.

Table 1 - Mean relative error of displacement field for different test velocities

	1mm/mim	2mm/mim	5mm/mim	10mm/mim
RTV 615	29.44%	7.93%	19.7%	26.44%

The DIC technique was shown to be suitable for the measurement of displacement fields in hyper-elastic materials.

For the constitutive models examined, it was found that the models of Ogden and Yeoh lead to better results, namely a lower error for the offset. However, these models do not fully characterize the hyper-elastic behavior of the tested specimens, high local deviations between the numerical simulation and experimental measurements were found.

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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 full versions 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. This e-book is complemented by an accompanying printed Book of Abstracts containing the extended abstracts of all presentations.

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.

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Resumo: In recent years, the study of polymers like polydimethylsiloxane materials (PDMS) has become a great interest field due its growing used in biomechanics applications. In this work the Digital Image Correlation (DIC) is proposed for the measurement of the continuous displacement field. This experimental optical technique allows the measurement with high resolution and without contact of the large displacements at the material surface and, therefore, is considered the most suitable technique for the mechanical characterization of hyper-elastic materials. The numerical simulations were implemented by using the commercial finite elements program Ansys r. This combines the experimental information taken from the tensile test performed in PDMS with material constitutive models to reproduce the experimental displacement fields observed during the experimental test. For this study, different constitutive hyper-elastic material models were analysed, namely: the MooneyRivlin model, Ogden model and Yeoh models.
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