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# BOOK OF ABSTRACTS

## ICSAAM 2015

### The 6th International Conference on Structural Analysis of Advanced Materials

8-11 September, 2015, Porto, Portugal

# 6th International Conference on Structural Analysis of Advanced Materials

Porto, Portugal

8 - 11 September, 2015

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Published by:
INEGI – Instituto de Engenharia Mecânica e Gestão Industrial
Front cover figures credits:
VC Pinto, PMGP Moreira
Editor ICSAAM2015 book of abstracts: VC Pinto, PMGP Moreira, PJS Tavares
**ISBN:** 978-972-8826

http://icsaam2015.inegi.up.pt

Sponsors

Institute of Mechanical Engineering and Industrial Management

University Politehnica of Bucharest

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SPM – Sociedade Portuguesa de Materiais

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# ICSAAM2015 Program

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Technical Program

*August 14th, 2015*

**TUESDAY, 8 September 2015**

| TUE, 09:00 - 09:30 | OPENING SESSION | Room Newton |
|---|---|---|
| Welcome to Participants<br>**(Conference Co-Chairs)**<br>Welcome Address | | |

| TUE, 09:30 - 10:15 | PLENARY LECTURE 1.1 | Room Newton |
|---|---|---|
| **Modelling extreme deformation and dynamic behavior of materials using multi-scale techniques and mesh-less methods**<br>**Professor Raj Das**<br>(University of Auckland, New Zeland)<br>Chair: Professor George Papanicolaou (University of Patras) | | |

| WED, 10:15 - 11:00 | PLENARY LECTURE 1.2 | Room Newton |
|---|---|---|
| **Structural Monitoring and Biomechanics**<br>**Professor Mário Vaz**<br>(Faculty of Engineering of University of Porto, Portugal)<br>Chair: Prof. George Papanicolaou (University of Patras, Greece) | | |

| **TUE, 11:00 - 11:30** | **COFFEE-BREAK** | **Lounge** |
|---|---|---|
| | | |

| TUE | Session 1A<br>11:30-12:45 | TUE | Session 1B<br>11:30-12:45 |
|---|---|---|---|
| TOPIC: Testing I<br>Chair: Mário Vaz | | TOPIC: Nanocomposites<br>Chair: Viviana Correia Pinto | |
| Ref: | Title and Author (s) | Ref: | Title and Author (s) |
| #15 | Investigation of the mechanical properties of carbon nanotube reinforced composites and their evaluation using a cylidrical RVE<br>**M. Konstantakopoulou**, G. Kotsikos | #20 | Effect of clay modifier on the rheometric behavior and mechanical/thermal aging properties of styrene-butadiene rubber-clay nanocomposites<br>**E. M. Sadek**, D. E. El-Nashar, S.M.Ahmed |
| #27 | Mechanics crack growth-based fatigue evaluation considering crack closure and equivalent initial flaw size<br>A.S.F. Alves, **J.A.F.O. Correia**, A.M.P. De Jesus, P.J.S. Tavares, P.M.G.P. Moreira | #42 | A comparative study of nanotube-epoxy interphasial interaction in CNT and TNT-epoxy matrix nanocomposites<br>**G.C. Papanicolaou**, D.V. Portan |
| #26 | Theoretical and experimental study of specimens with stress concentrators in dependance of stress triaxiality Donka **Ana Maria Comanici**, Viorel Goanta, Paul Doru Barsanescu | #43 | Enhanced Performances of Dye Sensitized Solar Cells based on Hybrid Photoanodes<br>**D.A. Chalkias**, D.I. Tasiopoulos, G.C. Papanicolaou |
| #66 | Deformability behaviour of new cobalt based alloys<br>Alexandru Ghiban, **Brandusa Ghiban**, Nicolae Serban, Cristina Maria Bortu | #46 | Viscoelastic Behavior and Modeling of nano and micro $TiO_2$ Powder-Epoxy Resin Composites<br>**L.C. Kontaxis**, A.E. Manara, G.C. Papanicolaou |
| #58 | Experimental investigation on Self-healing efficiency of doped Fiber Reinforced Plastics with Thermoplastic micro-Particles<br>A. Kotrotsos, A. Baltopoulos, S. Tsantzalis, X. Tsilimigkra, P.Tsokanas, **V. Kostopoulos** | #55 | Effect of $TiO_2$ Nanotubes Developed on Pure Titanium Substrates on the Mechanical Performance of Titanium-Titanium Single lap Adhesive Joints<br>**D.V. Portan**, G.N. Petropoulos, G.C. Papanicolaou |

| TUE, 12:45 - 14:15 | LUNCH | Lounge |
|---|---|---|

| TUE | Session 2A<br>14:15-15:30 | Room A | TUE | Session 2B<br>14:15-15:30 | Room B |
|---|---|---|---|---|---|
| TOPIC: Polymers and Polymer Matrix Composites<br>Chair: Gabriel Jiga | | | TOPIC: NDT-NDI techinques & others<br>Chair: Paulo Tavares | | |
| Ref: | Title and Author (s) | | Ref: | Title and Author (s) | |
| #7 | Fiber length influence and filament interaction on single and multifilaments<br>**Alexander Maier**, Armin Salimi, Ralf Schledjewski | | #35 | Digital image correlation measurements in an innovative railway car body underframe 3-point bending test<br>**Tiago Ramos**, Shayan Eslami, Paulo J. Tavares, P. M. G. P. Moreira | |
| #22 | Outdoor weathering of starch-graftedpolypropylene/kenaf fibres composite<br>**Amel Hamma**, Said Bouhelal, Alessandro Pegoretti | | #36 | Digital image correlation for structural health monitoring of an innovative proposal for seismic resistant structures<br>**Tiago Ramos**, André Furtado, Shayan Eslami, Sofia Alves, Hugo Rodrigues, António Ârede, Paulo J. Tavares, P.M. G. P. Moreira | |
| #68 | Synthesis of geopolymer material from metakaolin and Portland cement<br>**Oualit. Mehena**, Abadlia. Med.Tahar, Jauberthie. Raoul | | #70 | Wireless strain gauge for composite materials<br>**Šmelko Miroslav**, Praslička Dušan, Draganová Katarína, Lipovský Pavol, Kán Viktor, Bajús Ján | |
| #77 | Naturally occurring abietic acid for liquid crystalline epoxy curing agents<br>**Rasha A. Ibrahim El-Ghazawy**, Ashraf M. El-Saeed, Hessin I. El-Shafey, Abdel-Raheim M. Abdel-Raheim, Maher A. El-Sockary | | #71 | Influence of ultrasounds in the damping capacity of aluminium alloys<br>H. Puga, **V.H. Carneiro** | |
| #59 | Strategies on implementing a potential self healing functionality in a composite structure<br>X. Tsilimigkra, A. Baltopoulos, S. Tsantzalis, **A. Kotrotsos**, N. Siakavellas, V. Kostopoulos | | #19 | Acoustic emission monitoring fracture of a composite material<br>Cristian Cătălin Petre, Gabriel Jiga, **Mihai Valentin Predoi**, Cristian Diba, Marian Soare | |

| TUE, 15:30 - 16:00 | COFFEE-BREAK | Lounge |
|---|---|---|

| TUE | Session 3A<br>16:00-17:30 | Room<br>A | TUE | Session 3B<br>16:00-17:30 | Room<br>B |
|---|---|---|---|---|---|
| TOPIC: Analytical and Numerical Modeling I<br>Chair: Sérgio Tavares | | | TOPIC: Polymer Matrix Composites, Sandwich and Green Composite Structures<br>Chair: George Papanicolaou | | |
| Ref: | Title and Author (s) | | Ref: | Title and Author (s) | |
| #3 | Influence of deformability of horizontal diaphragms in their plan on the seismic loads distribution to resisting walls<br>**A. Benanane**, A. Ouazir, S. Benanane, M. Titoum, G. Mezoudj | | #81 | Development of composite materials database for aerospace certification<br>**Ho-Sung Lee**, Kyung-Ju Min | |
| #4 | A modern methodology of design of three-dimensional structures by a genetic algorithms approach<br>**S. Benanane**, D. Kerdal, A. Benanane, A. Ouazir, M. Titoum | | #82 | Dynamic behavior of composite plates made with green materials<br>**Florin Baciu**, Anton Hadăr, Horia Gheorghiu, Mihaela Sava, Bolcu Dumitru | |
| #6 | Surface structural inhomogeneities and fractal properties of MnO2 semiconductor thin films<br>**L. Skatkov**, V. Gomozov, S. Deribo | | #84 | Macroporous green ceramics by simultaneous recycling of coal ash and glass wastes<br>**Enikö Volceanov**, Simona Badea, Camelia Cristea, Alexandru Micu, Alberto Ion, Mihai Eftimie, Adrian Volceanov | |
| #30 | Multibody dynamics simulation of an electric bus with flexible parts<br>**Ricardo R. Teixeira**, Sérgio R. D. S. Moreira, S. M. O. Tavares | | #52 | Green composite materials: the breaking new ground ABC-matrix<br>D.E. Anastasiou, L.C. Kontaxis, G.C. Papanicolaou | |
| #92 | Finite element analysis in the design of patient-specific osteotomies guides. case study<br>**Anton Hadar** | | #8 | Composite magnetic microwires – sandwich structure for sensor application<br>**A. Chizhik**, A. Stupakiewicz, A. Zhukov, J. Gonzalez | |
| #11 | Homogenization of a fibred structure with a condition on the interface matrix-fibre<br>**H. Samadi**, M. Eljarroudi | | | | |

| TUE, 17:30 – 18:00 | POSTER SESSION | Exhibition Area |
|---|---|---|
| | | |

| TUE, 18:00 - 19:30 | WELCOME RECEPTION | Taylor's Port Cellars |
|---|---|---|
| | | |
| COCKTAIL RECEPTION<br>by courtesy of Taylor's<br>Taylor's Port | | |

## WEDNESDAY, 9 September 2015

| WED, 09:30 - 10:15 | PLENARY LECTURE 2.1 | Room Galileu |
|---|---|---|
| **Thermoset versus Thermoplastic composites: from raw materials and semi-products to final parts**<br>**Professor António Torres Marques**<br>(Faculty of Engineering of University of Porto, Portugal)<br>Chair: Professor Prof. Stefan Pastrama (University Politehnica of Bucharest) | | |

| WED, 10:15 - 11:00 | PLENARY LECTURE 2.2 | Room Galileu |
|---|---|---|
| **A comparative study of nanotube-epoxy interphasial interaction in CNT and TNT-epoxy matrix nanocomposites**<br>**Professor George Papanicolaou**<br>(University of Patras, Greece)<br>Chair: Prof. Gabriel Jiga (University Politehnica of Bucharest) | | |

| **WED, 11:00 - 11:30** | **COFFEE-BREAK** | **Lounge** |
|---|---|---|
| | | |

| WED, 11:30 - 12:15 | PLENARY LECTURE 2.3 | Room Galileu |
|---|---|---|
| **Virtual bronchoscopy method based on a graphical processor unit implementation of the marching cubes algorithm**<br>**Professor Stefan Pastrama**<br>(University Politehnica of Bucharest)<br>Chair: Prof. António Torres Marques (Faculty of Engineering of University of Porto, Portugal) | | |

| **WED, 12:15 - 14:15** | **LUNCH** | **Lounge** |
|---|---|---|
| | | |

| WED | Session 4A<br>14:15-15:30 | Room<br>A |
|---|---|---|
| TOPIC: Fatigue<br>Chair: Stefan Dan Pastrama | | |
| Ref: | Title and Author (s) | |
| #18 | Crack initiation analysis under mean stress effect in 2024 T351 Al-alloy<br>**Mustapha Benachour**, Nadjia Benachour, Mohamed Benguediab | |
| #28 | Stress intensity factors of a compact mixed mode specimen: finite element analysis<br>**S. M. O. Tavares**, D. Peixoto, P. J. Tavares, P.M.G.P. Moreira | |
| #85 | Comparison between three fatigue damage models and experimental results for composite materials submitted to spectrum loading<br>**Mohammed Bousfia**, M. Aboussaleh, B. Ouhbi | |
| #86 | Fatigue Analysis of a Hopper Knuckle Connection of a 181k Ton DWT Bulk Carrier under Global and Local Loads<br>**V K Kapnopoulou**, P A Caridis | |
| #62 | Study of effect of R-ratio on fatigue crack growth using Artificial Neural Network<br>**K.N.Pandey**, Chetan Swaroop | |

| WED | Session 4B<br>14:15-15:30 | Room<br>B |
|---|---|---|
| TOPIC: Manufacturing Techniques<br>Chair: Pedro Moreira | | |
| Ref: | Title and Author (s) | |
| #14 | Viability analysis of double cold wire gas metal arc welding process<br>**R. A. Ribeiro**, P. D'Angelo Assunção, E.M. Braga | |
| #34 | Friction stir welding of polymers: review and prospects<br>**Shayan Eslami**, Paulo J. Tavares, P. M. G. P. Moreira | |
| #89 | Friction stir weld-bonded aluminum joints<br>**Daniel F. O. Braga**, L. M. C. de Sousa, V. Infante, Lucas F.M. da Silva, P. M. G. P. Moreira | |
| #73 | Optimization of milling parameters to improve the surface roughness using the Taguchi methodology<br>Alberto Blanca, Jorge Meireles, Hernâni Lopes, **João Ribeiro** | |
| #88 | Structural glass – material for members and parts of load-carrying structures in civil engineering<br>**Marcela Karmazínová**, Jindrich Melcher, Ondřej Pešek | |

| WED, 15:30 - 16:00 | COFFEE-BREAK | Lounge |
|---|---|---|

| WED | Session 5A<br>16:00-17:30 | Room<br>A |
|---|---|---|
| TOPIC: Analytical and Numerical Model II<br>Chair: Paulo Tavares de Castro | | |
| Ref: | Title and Author (s) | |
| #78 | Three dimensional free vibration analysis of rotating Functionally Graded cylindrical shells in thermal environment<br>Abbas Ali Jami,**Esmaeil Bahmyari** | |
| #5 | Analysis of conditions for transition of multiple cracks into single main crack located in stress concentration zones under low-cycle fatigue loading regime<br>**Nikolay A.Makhutov**, Vladimir V. Zatsarinniy, Dmitry O. Reznikov | |
| #16 | An analytical model to estimate the maximum tensile stress in spliced beams under tensile load – using the example of a fivefold laminate<br>**René Ringli**, Thomas Vogel | |
| #72 | Biomechanical analysis of PDMS channels using different hyperelastic constitutive models<br>Cátia Cardoso, Carla Fernandes, Rui Lima, **João Ribeiro** | |
| #76 | A procedure to obtain the probabilistic Kitagawa-Takahashi diagram<br>**J.A.F.O. Correia**, A.M.P. De Jesus, R. Brighenti, P.M.G.P. Moreira, R.A.B. Calçada, A. Fernandez-Canteli | |
| | | |

| WED | Session 5B<br>16:00-17:30 | Room<br>B |
|---|---|---|
| TOPIC: Testing II<br>Chair: José Correia | | |
| Ref: | Title and Author (s) | |
| #63 | Effect of aluminosilsesqioxane addition and various curing conditions on the thermomechanical properties of glass fiber reinforced epoxy composite<br>**Danuta Matykiewicz**, Mateusz Barczewski, Beata Dudziec | |
| #75 | Validation of the dynamic behavior of composite materials with discontinuities<br>**Mihaela Sava**, Anton Hadăr, Ioan Părăuşanu, Florin Baciu, Stănescu Marius Marinel | |
| #90 | Mechanical properties of magneto sensitive elastomer with iron particles at uniform magnetic field intensity<br>**Sneha Samal**, Jarmil Vlach, Pavel Kavan | |
| #65 | Plasticity Determination of CoCrMoTi alloy<br>Alexandru Ghiban, **Brandusa Ghiban**, Nicolae Serban, Cristina Maria Bortun | |
| #66 | Deformability behaviour of new cobalt based alloys<br>Alexandru Ghiban, **Brandusa Ghiban**, Nicolae Serban, Cristina Maria Bortun | |
| #1 | Valorisation of industrial waste<br>**Didouche Yasmina-Fadhéla** | |

| **WED, 18:30 - 23:00** | **BANQUET** | Casa da Música |
|---|---|---|
| | | |
| CASA DA MÚSICA VISIT followed by CONFERENCE BANQUET<br>courtesy of Casa da Música<br>Casa da Música, Porto | | |

## THURSDAY, 10 September 2015

| THU, 09:30 - 10:15 | PLENARY LECTURE 3.1 | Room Galileu |
|---|---|---|
| **Material and shape crash-box influence on the evaluation of the impact energy absorption capacity during a vehicle collision**<br>**Professor Gabriel Jiga**<br>(University Politehnica of Bucharest, Romania)<br>Chair: Dr. Pedro Moreira (INEGI) | | |

| THU, 10:15 - 11:00 | PLENARY LECTURE 3.2 | Room Galileu |
|---|---|---|
| **Constitutive law describing the strength degradation of fiber reinforced composites subjected to cyclic loading**<br>**Professor Alberto D'Amore**<br>(Second University of Naples-SUN, Italy)<br>Chair: Prof. Mário Vaz (Faculty of Engineering of University of Porto) | | |

| **THU, 11:00 - 11:45** | **COFFEE-BREAK** | **Lounge** |
|---|---|---|
| | | |

| THU, 11:45 - 12:15 | PLENARY LECTURE 3.3 | Room Galileu |
|---|---|---|
| **Time-Dependent Behavior of Polymers: Viscoelasticity/Viscoplasticity and Physical Aging**<br>**Professor Rui Miranda Guedes**<br>(Faculty of Engineering of University of Porto, Portugal)<br>Chair: Professor George Papanicolaou (University of Patras) | | |

| **THU, 12:45 - 14:15** | **LUNCH** | **Lounge** |
|---|---|---|
| | | |

| THU, 14:15-15:30 | Session 6 | Room Newton |
|---|---|---|
| TOPIC: Degradation, durability and corrosion<br>Chair: Rui Miranda Guedes | | |
| Ref: | Title and Author (s) | |
| #23 | The electrochemical investigation on corrosion behavior of two titanium aluminide in aqueous environments<br>**Alexandra Banu**, Marcu Maria, Alexandru Paraschiv, Oana Trusca | |
| #24 | New coatings for short-term oxidation protection of titanium aluminide at 850°C<br>**Maria Marcu**, Alexandra Banu, Luminita Georgescu,Cristina Juganaru | |
| #25 | DSC analysis of titanium aluminde correlated with short term oxidation behavior<br>**Alexandra Banu**, Marcu Maria, Elena Anghel, Cristian Doicin | |
| #74 | Degradation analysis of fiber-metal laminates under service conditions to predict their durability<br>**A.Viandier**, D. Stefaniak, C. Hühne, M. Sinapius | |
| #87 | A 'complete' characterization study of anomalous behaviour of hygrothermally aged FRPs<br>**Sotirios A. Grammatikos**, Mark Evernden | |

| THU, 15:30-16:00 | COFFEE-BREAK | Lounge |
|---|---|---|
| | | |

| THU, 16:00-17:00 | Session 7 | Room Newton |
|---|---|---|
| TOPIC: Polymers and Polymer Matrix Composites II<br>Chair: Daniel F. O. Braga | | |
| Ref: | Title and Author (s) | |
| #2 | Stable and degradable all-aliphatic polyurethane elastomers<br>**Milena Špírková**, Magdalena Serkis, Rafał Poręba, Jiří Hodan, Jana Kredatusová, Luďka Machová, Dana Kubies | |
| #10 | The accelerated effect of nanoparticles on the degradation of the thermomechanical properties of a bio-based polymer<br>**Evagelia Kontou** | |
| #95 | Optimization of the hybrid viscoelastic interphase model<br>**Psarra Erato**, Papanicolaou George | |

| THU, 17:15 – 17:45 | CLOSING SESSION | Room Newton |
|---|---|---|
| **Conference Organizing Committee** | | |

| TUE, 17:30 – 18:00 | POSTER SESSION | Exhibition Area |
|---|---|---|

| Ref: | Title and Author (s) |
|---|---|
| #21 | Dynamic mechanical properties of PLA and PLA/CNT-COOH biodegradable nanocomposites thin film<br>Viviana Correia Pinto, Marta Martins, Nuno Rocha, Rui Miranda Guedes |
| #29 | Experimental and numerical analysis of creep and stress relaxation behaviour of PLA-PCL fibres<br>Cátia Martins, Viviana Correia Pinto, Rui Miranda Guedes, António T. Marques |
| #44 | Preparation of PVP Polymer Electrolytes and their Application in Solid State Dye Sensitized Solar Cells<br>D.I. Giannopoulos, D.A. Chalkias, G.C. Papanicolaou |
| #45 | Low energy impact and post impact behavior of epoxy matrix-woven flax fabric composites<br>D.A. Chalkias, A.F. Koutsomitopoulou, G.C. Papanicolaou |
| #47 | Strain rate effects in micro and nano TiO2 epoxy resin particulate composites<br>A.E. Manara, L.C. Kontaxis, G.C. Papanicolaou |
| #48 | Thermal Shock Cycling Effect on the Flexural Stress Relaxation Behavior of Glass-Epoxy Composites<br>E.A. Tsiangou, L.C. Kontaxis, G.C. Papanicolaou |
| #49 | The double role of fibers as reinforcements and heating elements for polymer curing in thermoset matrix-fiber composites<br>I. E. Chontzoglou, L.C.Kontaxis, G.C. Papanicolaou |
| #50 | Modeling the Mechanical Degradation Due to Moisture Absorption in Polymer Matrix Composites<br>P.D. Fotou, G.C. Papanicolaou |
| #51 | Modeling and Experimental Investigation of the inclusion geometry and concentration effect on the quasi-static properties of a semi-green epoxy matrix<br>F.K. Kozaniti, L.C. Kontaxis, G.C. Papanicolaou |
| #53 | Development of a Starch Reinforced Chios mastic- olive oil matrix new green composite material<br>D.E. Anastasiou, L.C. Kontaxis, G.C. Papanicolaou |
| #54 | Nitinol layered composites: manufacturing and electrical properties<br>E.J. Pappa, G.C. Psarras, D.V. Portan, G.C. Papanicolaou |
| #60 | Thermomechanical characterization of epoxy/carbon black/graphene oxide hybrid nanocomposites<br>A. Stimoniaris, D. Gournis, M. Karakassides, C. Delides |
| #61 | Monitoring the fly ash dispersion in epoxy matrix and its effect on the thermomechanical properties of the obtained composites<br>Adamos Stimoniaris, Haralampos Zois, Athanasios Kanapitsas, Michael Karakassides, Constaninos Delides |
| #64 | Effect of pigments addition on properties of the isotactic polypropylene<br>Mateusz Barczewski, Bartłomiej Hoffmann |
| #69 | Use of Different Acids for the Extraction of Chromium Contained in Ash from the Incineration of Waste Leather<br>Alexandru Ghiban, Brandusa Ghiban, Nicolae Serban, Cristina Maria Bortun |
| #80 | Hydrogen gas sensors based on Palladium/Silicon Oxide/Ailicon Carbide sandwich structures<br>Jenica Neamtu, Florea Craciunoiu, Dragos Ovezea, Razvan Pascu |
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| #91 | Relationship chemical surface treatments for aluminum structural bond strength<br>Vinšová Lenka, Jarmil Vlach, Kořínek Jan |
| #93 | Influence of temperature on mechanical properties of polypropylene sandwich panel and compare the mechanical properties of the aluminum honeycomb panels<br>Lukasova Vera, Kavan Pavel |

# Abstracts

# Session 1A

TUE, 11:30-12:45

Room A

TOPIC: Testing I

Chair: Mário Vaz

#73

# OPTIMIZATION OF MILLING PARAMETERS TO IMPROVE THE SURFACE ROUGHNESS USING THE TAGUCHI METHODOLOGY

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**ABSTRACT**

Manufacturing industry is one of the most important industries in the developed countries. This industry uses different machining techniques like drilling, turning, milling as well as the combination of those techniques.

Depending on machining aim and for each cutting tool there are different combinations of parameters, like feed rate, spindle speed, axial or radial depth of cut to obtain different results in terms of quality of machined surface and tool wear. Each cutting parameters combination will result in a different surficial roughness of workpiece and tool life. However, it is very difficult to define the best combination that provides the lower surface roughness and maximum tool life [1].

One of the most important features in the manufacturing industry is to predict the surface roughness and tool life for a particular combination of machining parameters in order to choose the best combination for producing a part [2, 3]. Furthermore, is essential to reduce the costs for the required quality.

This paper presents a study of Taguchi design application to optimize surface quality in a CNC milling operation. Maintaining good surface quality usually involves additional manufacturing cost or loss of productivity. The Taguchi design is an efficient and effective experimental method in which a response variable can be optimized, given various control and/or noise factors, using fewer resources than a factorial design. This study includes feed per tooth, cutting speed and radial depth of cut as control factors. An orthogonal array of L9(34) was implemented and the ANOVA analyses were carried out to identify the significant factors affecting surface roughness as well as the determination of optimal cutting combination by seeking the best surface roughness (response) and signal-to-noise ratio.

In this study we have machined a cylindrical hardened plastic mould steel (GMTC 1.2738) specimen using a milling tool provided by Palbit® which the reference is PLUS 49095 / WNHU 04T310.

The experimental work was done in the milling machine Deckel Maho DMC 63V and the cutting parameters were combined agreeing the defined Taguchi orthogonal array (table 1), the only parameter maintained fixed was the axial depth with a value of 0.3 mm. Between each experiment, the roughness was measure on three different points of specimen using a portable surface roughness tester (Mitutoyo SJ-301).

The results were analyzed and statistical treated to obtain the best combination in terms of surficial roughness and the influence of each cutting parameter in the surface quality.

In the table 1 is presented the Taguchi orthogonal array, the average of the measured roughness and the signal to noise ratio which, is this case, was chosen the “smaller is the better” in order to minimize the surface roughness.

**Table 1.** Taguchi orthogonal array, S/N and average roughness values.

| Experiment | $V_c$ [m/min] | $f_z$ [mm/tooth] | $A_e$ [mm] | Roughness [µm] | S/N [dB] |
|---|---|---|---|---|---|
| **1** | 150 | 0,1 | 0,075 | 2,44 | -7,776 |
| **2** | 150 | 0,15 | 0,1 | 2,39 | -7,567 |
| **3** | 150 | 0,2 | 0,125 | 2,6 | -8,286 |
| **4** | 180 | 0,1 | 0,1 | 2,19 | -6,834 |
| **5** | 180 | 0,15 | 0,125 | 1,94 | -5,751 |
| **6** | 180 | 0,2 | 0,075 | 2,18 | -6,757 |
| **7** | 200 | 0,1 | 0,125 | 2,05 | -6,217 |
| **8** | 200 | 0,15 | 0,075 | 2,28 | -7,168 |
| **9** | 200 | 0,2 | 0,1 | 2,03 | -6,172 |

Analyzing the table 1, is possible to observe that the cutting parameters combination of experiment 5 gives the lower value of roughness and signal to noise ratio.
With all the roughness measurements, was implemented an ANOVA analysis using the Statgraphics® software. The results are shown in table 2.

**Table 2**. ANOVA results. Sum of Squares Type III

| *Source of Variance* | *Sum of Squares* | *df* | *Mean Squares* | *F-Ratio* | *P-value* |
|---|---|---|---|---|---|
| MAIN EFFECTS | | | | | |
| A:Vc | 0,266867 | 2 | 0,133433 | 3,52 | 0,2212 |
| B:fz | 0,00686667 | 2 | 0,00343333 | 0,09 | 0,9169 |
| C:ae | 0,0200667 | 2 | 0,0100333 | 0,26 | 0,7907 |
| RESIDUAL | 0,0758 | 2 | 0,0379 | | |
| TOTAL | 0,3696 | 8 | | | |

Evaluating the ANOVA analysis, it is possible to observe that the most important factor is the Cutting Speed (Vc) with a P-value=0,22 and the feed rate (fz) has the lower effect in the value of roughness. Due to the low number of degrees of freedom, we must be cautious with the results, however for a preliminary test, the results are good enough for the industry application.

**References**

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# BIOMECHANICAL ANALYSIS OF PDMS CHANNELS USING DIFFERENT HYPERELASTIC CONSTITUTIVE MODELS

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**ABSTRACT**

A constitutive model for a mechanical analysis is a relationship between the response of a body (for example, strain state) and the stress state due to the forces acting on the body, which can include the environmental effects. A wide variety of material behaviours are described with a few different classes of constitutive equations [1].
The hyperelastic models have been used extensively to model the non-linear behaviour and anisotropic material, since the soft tissues under large deformations often regain their elasticity. The constitutive behaviour of hyperelastic materials is defined in terms of deformation energy potential [2].
In this study, were performed simulations of Newtonian fluid flow in channels with disorders such as the aneurysms. The main goals of these simulations were to analyse the fluid flow in the channels and the mechanical behaviour of channels walls. The material used for channels was the PDMS which has a hyperelastic behaviours and to simulate that structure were used different constitutive models, under the same conditions, aiming to analyse the most appropriate model for this type of study. Thus, the deformations suffered were visualized on the walls of the channels, caused by the internal pressure induced by the internal fluid.
It was used Ansys® - *Fluent* software, to perform the simulation of the Newtonian fluid flow (glycerin, with well-known properties and sufficient viscosity to measure the pressure drops), in order to determine the speed and the internal pressure. This pressure, approximately $11.742e^{-6}$ MPa for an input flow rate of 300 µL/min, was imported into the channels in Ansys® - Static Structural, in order to be able to evaluate and analyse the deformations and stresses in the channel wall, caused by internal pressure induced by the fluid flow. To do this, was used the most known hyper-elastic constitutive models.Six constitutive models were simulated, they being: *Ogden* 2nd and 3rd *Order*, *Yeoh* 2nd and 3rd *Order* and *Mooney-Rivlin* 5 and 9 *Parameter*. All the analysed constitutive models converged for a solution.
The obtained results of numerical simulations for these six models showed little variation among them. This small variation is explained because the flaw rate used in the Fluent simulation induced a low pressure within the channel which caused a small deformation field and for these values all the constitutive models could follow the material mechanical behaviour. If the internal pressure is much higher, probably the results obtained for the different constituent models will be very different. In Fig. 1 is presented an example of the resulted obtained for two different constitutive models.

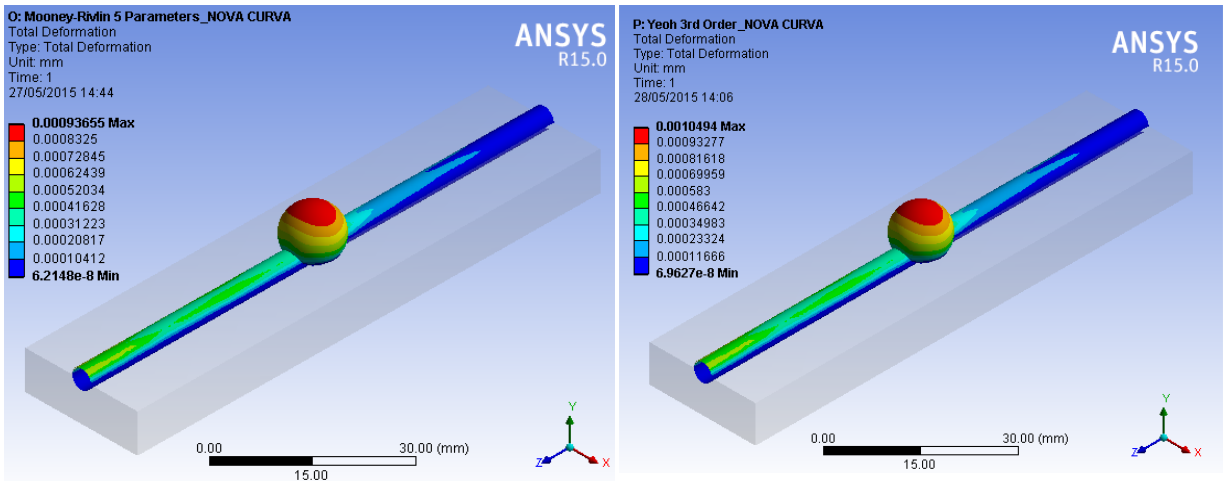


**Figura 1** - Total deformation occurred in the channel wall calculated by the constitutive model of Mooney-Rivlin 5 Parameter and Yeoh 3rd Order, respectively.

In the Table 1 is present the comparison among the maximum and minimum displacements obtained in the FEM simulations. It is possible to verify that the obtained displacements are very low for all the analysed models, even for maximum values. The standard deviation is also low that indicates the calculated values tend to be very close to the average and range from 0.755E-4 and 0.05E-8 for the maximum and minimum values.

**Tabela 1** Maximum and minimum values of the different models and mean and standard deviation corresponding.

| ***Constitutive model*** | ***Maximum value [mm]*** | ***Minimum value [mm]*** |
|---|---|---|
| *Mooney-Rivlin 5 Parameter* | 9,366E-04 | 6,215E-08 |
| *Mooney-Rivlin 9 Parameter* | 8,865E-04 | 5,883E-08 |
| *Ogden 2nd Order* | 10,27E-04 | 6,816E-08 |
| *Ogden 3rd Order* | 9,672E-04 | 6,418E-08 |
| *Yeoh 2nd Order* | 10,88E-04 | 7,216E-08 |
| *Yeoh 3rd Order* | 10,49E-04 | 6,963E-08 |
| *Average* | 9,924E-04 | 6,585E-08 |
| *Standard deviation* | 0,755E-04 | 0,500E-08 |

In summary, it is concluded that any constitutive model referred to above, can be applied to such studies, allowing the study behaviour of the PDMS channel wall, particularly for the analysis of stress and displacement field on the aneurysm. In further studies it would be interesting analyse the channel wall behaviour for higher internal pressures and for a Non Newtonian fluid which the properties were more close to blood.

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