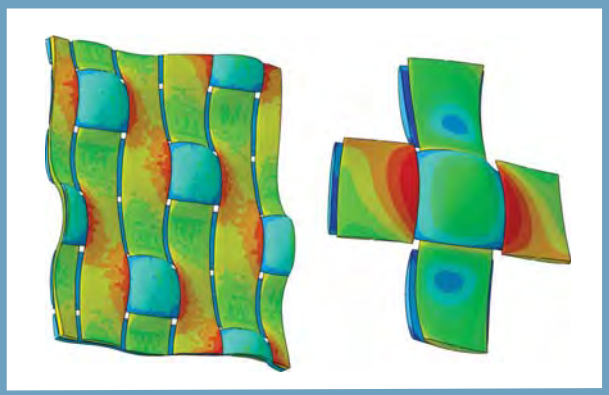
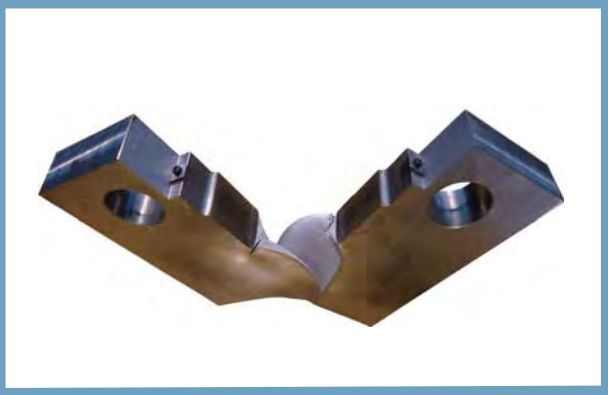
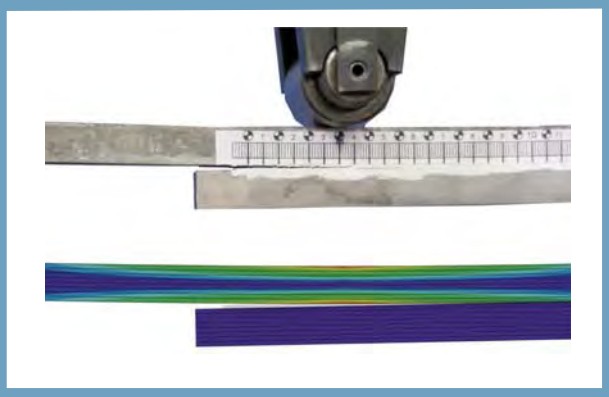
1st International Conference of the
International Journal of Structural Integrity

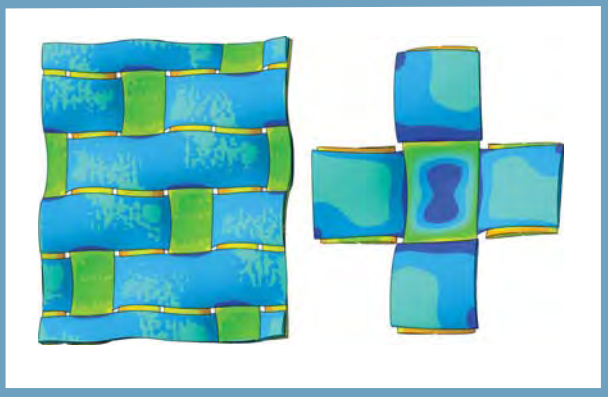
Faculty of Engineering, University of Porto, Portugal

June 25-28, 2012









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Welcome from Sebastião Feyo de Azevedo, Dean of Faculty of Engineering

DEAR PARTICIPANTS IN THE IJSI-2012 CONFERENCE,

AS DEAN OF THE FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO - FEUP it is my pleasure to welcome you in the 1st Int. Conference of the International Journal of Structural Integrity, IJSI-2012.

FEUP is for many years fully committed to research and international co-operation. In the particular of this conference, we have a long tradition of involvement in problems of structures, that started years ago with the civil engineering area and eventually spread to many other different areas of application, including the mechanical, aeronautical, materials and biomechanical fields.

Our activity is enhanced by the several RD institutes associated to our action. We enjoy today a recognized role in the international scene, in which we emphasize our co-operation with our European partners and our strong links with the Portuguese speaking countries in several continents.

I wish you have at FEUP a fruitful meeting, but, further to this opportunity of strengthening technical and scientific co-operation, I very much wish that you find the time and use this occasion not only to visit the very many attractions of the old City of Porto, world heritage site, including the 'must' of a visit to our port wine cellars, but also and mainly to learn more of an ancient friendly culture that comes from the distant days of Portus Cale, a village of roman influence set by the mouth of the Douro river *circa* 2200 years ago that led to the name Portugal.

With warm regards,

Sebastião Feyo de Azevedo
Professor of Chemical Engineering
Dean

Welcome from Paulo M.S.T. de Castro, Conference Chair

DEAR IJSI-2012 DELEGATES,

As chair of the organizing committee of the 1st Int. Conference of the International Journal of Structural Integrity, IJSI-2012, it is a pleasure to welcome you all to the Faculdade de Engenharia da Universidade do Porto, where the meeting takes place.

As its name implies, IJSI-2012 is a first event of the International Journal of Structural Integrity, a young journal now in its third year of existence, published by EMERALD under the editorial leadership of Professor Chris Rodopoulos.

The journal is sponsored by the European Aeronautics Science Network - EASN, indicating an emphasis on aeronautics in its contents. The journal does not, however, excludes other types of applications, as the perusal of the already published volumes will show and is again evidenced by the present event.

This conference starts an intended series that will certainly benefit from the experience gained in Porto, an ancient city whose historical center is UNESCO World Heritage.

Sincerely yours,

Paulo M.S.T. de Castro
Professor of Mechanical Engineering
Faculty of Engineering, University of Porto
Porto, Portugal

Conference Overview

HE INTERNATIONAL JOURNAL OF STRUCTURAL INTEGRITY - IJSI was launched in 2010 and is published in partnership with the European Aeronautics Science Network - EASN. The ISJI aims at a broad coverage of structural integrity issues, including material characterizations from the fracture and fatigue points to view, numerical modelling of those phenomena in materials and real structures, failure analysis methodologies and structural integrity evaluation criteria. The journal provides a forum for the key players in this broad area of science and technology, as universities, research institutes, manufacturing industry, legislative bodies and government agencies, SMEs, consultancy and maintenance companies. Occasionally scientific meetings are sponsored or even organized by the journal, as this 1st International Conference which will take place in Porto, Portugal. The conference aims at being a forum for discussion of current trends of research in structural integrity, in aeronautics and space, but also in other sectors of engineering where structural integrity is a key concern.

The conference topics are aligned with the IJSI coverage, and include but are not limited to:

- Advances in fracture analysis
- Coating technology and structural performance
- Design and structural assessment of metallic and composite structures
- Durability of metallic and composite structures
- Environmental effects and structural performance
- Evaluation of joining technologies
- Examination of computational codes for stress analysis and damage tolerance
- Nanomechanics and nanomaterials
- Non-destructive testing
- Probabilistic approach to damage tolerance
- Repair technologies
- Scale effects
- Structural ageing
- Structural health monitoring
- Structural integrity
- Structural performance evaluation of metals, composites, hybrids and polymers
- Surface engineering and structural performance

A Note on the History of the University of Porto

With more than one hundred years, the University of Porto was formally founded on 22nd March 1911, immediately after the Portuguese Republic was established. The roots of the institution, however, date back to 1762, when the Nautical Class was created by King D. José I. This school, along with subsequent schools which were created, were to be responsible for training students in Porto over the course of the eighteenth and nineteenth centuries, providing a response to the need for qualified staff in the fields of naval affairs, trade, industry and the arts.

In 1825, the first medical school was founded in Porto, entitled the Royal School of Surgery, which was transformed in 1836 into the Medical-Surgical School, as another axis of training at the University of Porto.

In parallel, the Sketching and Drawing Class gave rise to other schools - the Porto Academy of Fine Arts (1836), later the Porto School of Fine Arts (1881), and finally the Porto Higher Institute of Fine Arts (1950). The latter transformed over the last quarter of the twentieth century, into the current faculties of architecture and fine arts at the University of Porto.

While the University of Porto was initially structured around two faculties (Science and Medicine), over the course of the twentieth century, a diversification of knowledge arose and schools gained autonomy. Even during the 1st Republic, in 1915, the Technical Faculty was born (renamed the Faculty of Engineering in 1926), along with the Faculty of Arts in 1919 and the Faculty of Pharmacy in 1925. During the authoritarian regime, created after the military movement on 28th May 1926, growth at the University of Porto was conditioned: the Faculty of Letters was terminated in 1928, and only restored in 1961; only the Faculty of Economics was truly created from scratch during this period, in 1953.

After the revolution in April 1974, and until the end of the century, the University of Porto finally began to expand. The six existing faculties at the time were completed by a further eight: the Abel Salazar Institute of Biomedical Sciences (1975), the Faculty of Sport (1975), the Faculty of Psychology and Education Science (1977), Faculty of Architecture (1979), Faculty of Dental Medicine (1989), Faculty of Nutritional and Food Science (1992), Faculty of Fine Arts (1992) and Faculty of Law (1994). Today, the University of Porto has fourteen faculties and one post-graduate school, the Porto Management School, created in 1988 and whose name changed to University of Porto Business School in 2008.

A Few Paragraphs on the Faculty of Engineering

The teaching of Engineering in Portugal had its origins in 1762, in the early Nautical School (Aula Náutica). The city of Porto was an important shipping and trade centre, and the mercantile spirit of its inhabitants was early developed. However, those were very troubled times: trade was being adversely affected by pirates hiding along the shores of North Africa who plundered ships carrying goods.

To solve this problem, Porto businessmen asked the King's permission to build, at their own expense, two frigates to protect the fleets sailing from the city to the ports in America. Shipbuilding required men capable of commanding and manoeuvring the vessels, and thus the Nautical School was founded in Porto.

The Nautical School was later replaced by the Polytechnic Academy, where Engineering was taught in the Faculty of Sciences, which included the School of Engineering. In 1915, the School of Engineering was turned into an autonomous Technical Faculty and in 1926 it got today's name: Faculty of Engineering of the University of Porto (Faculdade de Engenharia da Universidade do Porto) FEUP.

Celebrating the 100th anniversary of the Polytechnic Academy, the building at Rua dos Bragas, its former location in the city center of Porto, was inaugurated in 1937.

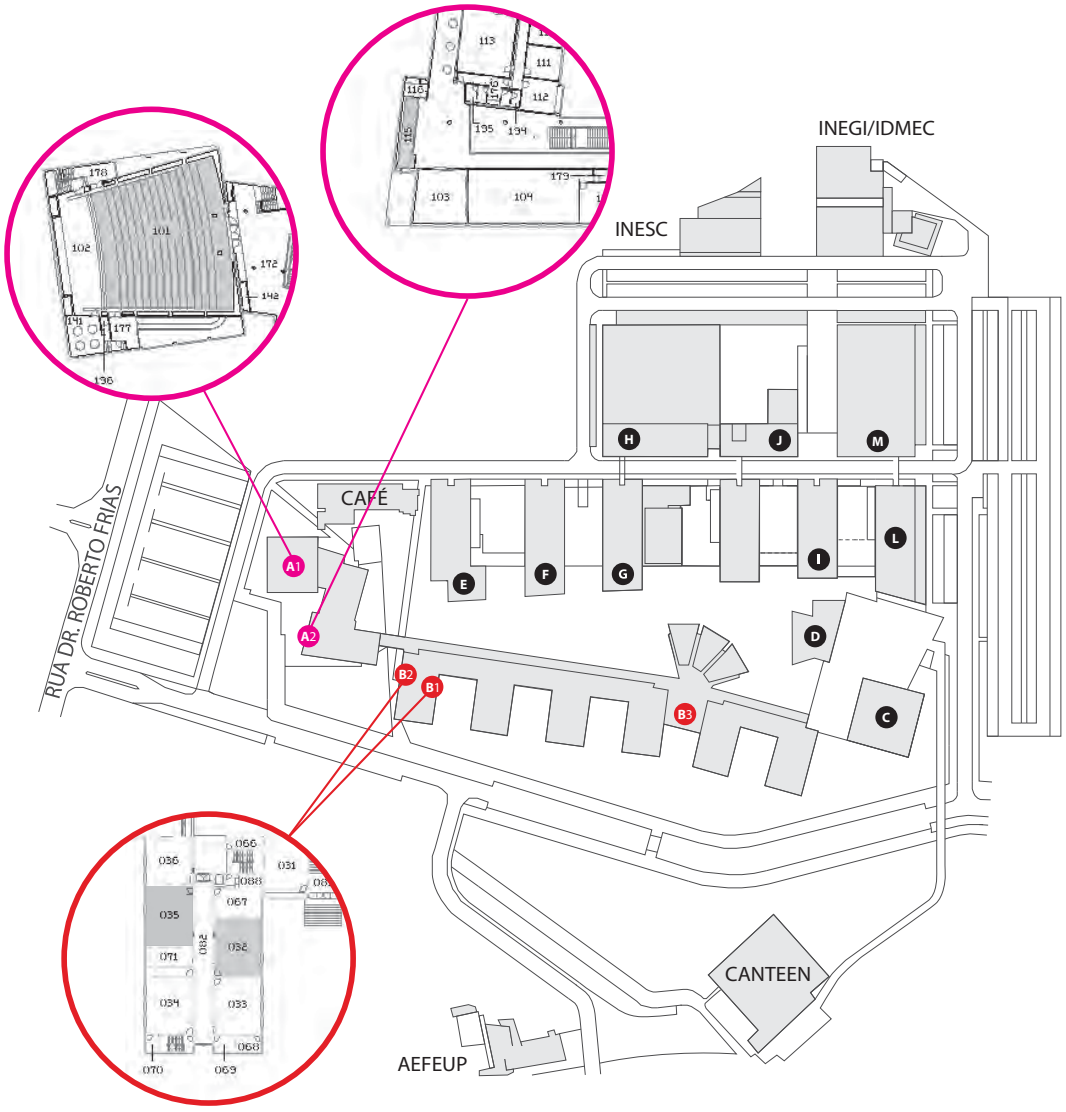
The Portuguese education reform of 1970 introduced important changes to the organization of Engineering programmes, which were shortened to five years (up to then Engineering programmes were six years long), and schools were given the autonomy to design their own curricula. In 1988, the publication of the law on university autonomy allowed the Faculty of Engineering to vote on its first statutes, which sanctioned its administrative, financial and pedagogic autonomy.

Postgraduate education is an area in which FEUP has invested substantially since the creation of its first Master in 1981. From then on, other Masters were developed, as well as Doctoral Programmes[1] and a wide offer of Continuing Education study programmes. Most of FEUP's students are nowadays enrolled in Integrated Masters programmes, five years long.

Since 2000, FEUP has new facilities located in University of Porto's Pole II - Asprela Campus. With almost three times the previous area, with incomparably superior conditions and quality, FEUP has a confident outlook into the future.

[1] The doctoral degree was awarded before, but not in the context of "doctoral programmes" including, further to research, a taught component.

Faculty of Engineering Map



A - ADMINISTRATION
1. Auditorium - A101
2. Secretariat - A115

B - CLASSROOMS AND SERVICES
1. Conference Room - B032
2. Conference Room - B035
3. Coffee lobby

C - LIBRARY

D - INFORMATICS CENTRE

E - DEPARTMENT OF CHEMICAL ENGINEERING (DEQ)

F - DEPARTMENT OF MINING ENGINEERING, AND DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING (DEM E DEMM)

G - DEPARTMENT OF CIVIL ENGINEERING (DEC)

H - DEPARTMENT OF CIVIL ENGINEERING (DEC NORTH)

I - DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING AND DEPARTMENT OF INFORMATICS ENGINEERING (DEEC E DEI)

J - DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING (DEEC NORTH)

L - DEPARTMENT OF MECHANICAL ENGINEERING AND DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT (DEMEC AND DEIG)

M - DEPARTMENT OF MECHANICAL ENGINEERING (DEMEC NORTH)

Plenary Invited Speakers

Claudio Dalle Donne, EADS Innovation Works

Metallic Technologies and Surface Engineering
EADS Innovation Works
81663 München
Germany

Lighter, Faster, Greener - Additive Layer Manufacturing for Aerospace Structures

with co-authors Jon Meyer, Frank Palm, Erhard Brandl, Laetitia Kirschner and Katja Schmidtke, EADS Innovation Works

ADDITIVE LAYER MANUFACTURING (ALM) is a revolutionary concept by which components are grown from the ground up, rather than machined from a larger block. Very complex geometries can be produced rapidly and directly from computer-aided design (CAD) information without the need for dies, form tools or molds. Additionally, ALM utilises significantly less raw material for any given component and produces negligible levels of waste in comparison to traditional machining processes, in which up to 90% of the material is removed. In this overview the Additive Layer Manufacturing is described and some examples of actual and potential applications are given. Furthermore key technology drivers are discussed and a special focus is given to the fundamental understanding of additive manufactured material properties, which is still at an early stage. For example, there is only little experience in predicting the effect of defects on the fatigue behavior. Such understanding of damaging mechanisms will be key to developed design rules for future primary structures applications.

Claudio Dalle Donne was born in Karlsruhe in 1965. He studied Mechanical Engineering at the Karlsruhe University of Technology and was awarded a doctorate there in 1996. From 1991 to 2004 he worked at the Institute of Materials Research of the German Aerospace Centre (DLR) in Cologne in various functions and departments (fatigue, fracture mechanics, friction stir welding). In 2004 he moved to the EADS Corporate Research Centre Germany (now EADS Innovation Works) as head of the "Metallic Structure" department. Since 2007 he has headed the transnational department "Metallic Technologies and Surface Engineering". Author or co-author of a large number of scientific papers and reports, Dr. Dalle Donne is currently the ICAF National Delegate for Germany, and member of the editorial board of the International Journal of Structural Integrity.

Jerzy Komorowski, NRC Institute for Aerospace Research

General Manager, NRC Institute for Aerospace Research
National Research Council Canada
1200 Montreal Road, M-3, Ottawa, ON K1A 0R6
Canada

The Age for Reason

with co-author Nicholas C. Bellinger

IN THE PAST, three design paradigms have been used to determine the life of aircraft structures; no-life, safe-life and damage tolerance.

The no-life paradigm was used to design the earliest commercial jet aircraft. Due to the fact that little information was available regarding the material systems used to fabricate aircraft, large safety factors were applied to the static strength of the different materials. In addition, the materials were assumed to be ideal continuous, homogeneous and isotropic. Not surprisingly, as aircraft entered into service, cracks formed in some components, which occasionally fractured resulting in the complete loss of an aircraft and in turn, fatalities. To improve aircraft design, a new paradigm was developed known as the safe-life methodology, which is currently used to design "safety" critical components, such as landing gears, in aircraft. Although this methodology assumes that all materials are ideal continuous, homogeneous and isotropic as in the no-life method, safety factors are applied to the fatigue (or endurance) limit to take into account material scatter. To reduce the risk of aircraft flying with unknown cracks, the damage tolerance methodology was developed, which assumes that all fatigue critical components contain growing cracks. In this methodology, the crack growth life is estimated, which drives directed in-service inspections allowing undamaged components to remain in service. Investigations that have been carried out over the years on failed components have revealed that these methodologies do not adequately take into account complex damage scenarios (such as wide-spread fatigue damage), environmental and age degradation modes (such as corrosion and fretting), improper damage repair and usage variability. In addition, as new material systems (such as fibre-metal laminates) and fabrication technologies (such as resin transfer moulding) are introduced into new aircraft designs, unanticipated failure mechanisms will develop due to cyclic and environmental loading. To address these concerns a new life management methodology, known as the Holistic Structural Integrity Process (HOLSIP), is being developed by an international consortium to augment and enhance traditional safe-life and damage tolerance methodologies in order to provide a powerful design and sustainment tool. This presentation will provide examples of the deficiencies of the current life methodologies and the need to move toward a physics-based method.

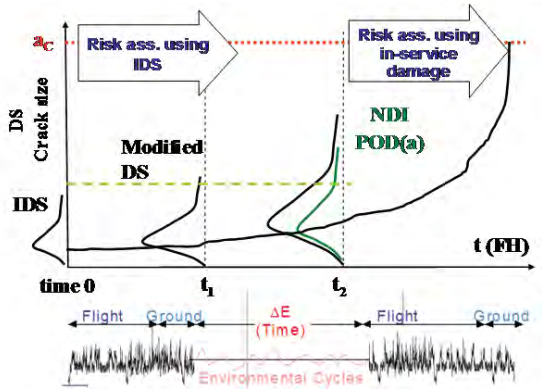


Figure: Holistic Structural Integrity Process.

On January 17, 2012, Jerzy Komorowski was appointed General Manager of NRC's Aerospace portfolio. Since April 2012, he has also served as the Interim GM for the Energy, Mines and Environment portfolio. Previously, Mr. Komorowski was Director General of the NRC Institute for Aerospace Research (IAR 2005-2012); Director of the Structures, Materials and Propulsion Laboratory at IAR (2002-2005); and leader of IAR's Structures Group (1998 to 2002). He joined IAR - formerly known as the National Aeronautical Establishment - in 1982.

Mr. Komorowski received his ME in applied mechanics from the Warsaw Technical University, Poland, in 1976. During his career, he has published more than 100 reports, journal and conference papers. His early research was focused on experimental strain analysis, as well as environmental effects in composite and metallic materials. In the 1990s, he was active in the field of non-destructive inspection, developing new optical inspection methods and pioneering models of the impact of corrosion on the integrity of aircraft structures. As Director of the Structures, Materials and Propulsion Laboratory, Mr. Komorowski helped it to become one of the leading research centres for holistic structural integrity design.

Mr. Komorowski is a graduate of NRC's LEAD Executive Challenge program. He is also a member of the Canadian Aeronautics and Space Institute; the Canadian voting member of the NATO Research and Technology Organization Advanced Vehicles Technology Panel (AVT); and Chair of the AVT Support Committee. He serves as the Canadian National Resource Specialist at the Aerospace Engineering Group of the Technical Cooperation Program.

As General Manager of NRC's Aerospace portfolio, Mr. Komorowski serves on the boards of directors of the Consortium for Research and Innovation in Aerospace in Quebec; Aéro Montréal - an industry cluster organization; EnviroTREC - the Canadian Environmental Test Research and Education Centre; and the Green Aviation Research & Development Network. He is also Deputy Chair of the Steering Committee of the Canadian Aerospace Environmental Technology Road Map.

Chris Rodopoulos, Monash University

Monash University
Victoria 3800
Australia

Fatigue damage discrepancies and the multiple stages of the similitude concept

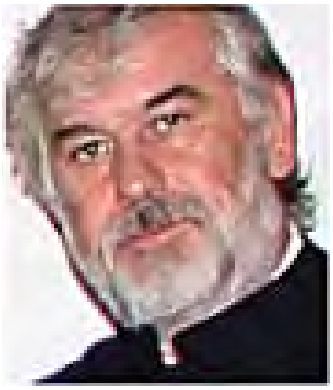
THE WORK demonstrates how the theory of the fatigue damage map (FDM) can be used in order to define a closed form locus where fatigue crack growth can be sought. The Intrinsic FDMLocus depending only on readily material properties represents a tool able to accurately predict crack growth of polycrystals. If the Locus is expressed in terms of a surface plot after triangulation of the data, it concludes into visualization of the potential for multiple similitude stages. The stages are defined as a function of the maximum far field stress and ΔK. Multiple similitude stages are found to dominate the short and near threshold area (Stage I growth) and represent direct result of the effect of polycrystalline behaviour to flow resistance. The work concludes that interrogation of the points defining the Intrinsic FDM Locus and related to the three thresholds can provide potential characteristics in the quest for an ideal damage tolerance material.

Chris Rodopoulos was born in Athens, Greece in 1967. In 1991 he received his Dipl.-Eng. in Mechanical Engineering from the University of Patras. In 1992 he received an MSc in Advanced Materials from Nottingham University. In 1996 he completed his PhD from the University of Sheffield. His research interests are focused on Surface Engineering Treatments, Fatigue Damage Tolerance Analysis, Theoretical Stress Analysis and Thermomechanical Fatigue of Metal Matrix Composites. He is the editor-in-chief of the International Journal of Structural Integrity, and the author of more than 120 papers and four books. Since 2002 he has led the Interest Group Surface Engineering Treatments with the European Aeronautics Science Network. He is a member of several professional organizations, including ASME, AIAA, ESIS and IMechE. During his career so far he has received 5 awards for research papers. He has strong collaborations with a number of key research institutes and industrial bodies including, EADS, Airbus UK, Boeing, Rolls-Royce, Hyundai, NRC-CNRC, NASA Langley, Applied Ultrasonics, Metal Improvement Company, CLFA, DLR, NLR, SIKA, Penetron, LAGARGE, etc.

Mário A. P. Vaz, Faculty of Engineering, University of Porto

Faculty of Engineering, University of Porto
Porto
Portugal

Experimental techniques for stress/strain assessment and structural monitoring



MECHANICALdesign is basically an exercise of creativity, triggered by specific needs. However, a deep understanding of materials behaviour and Solid Mechanics methods is necessary to achieve good project solutions. The engineering community continues to cross the boundaries of known practices in design and manufacturing techniques, looking for new materials and more efficient mechanical systems, new energy sources and their effects upon the environment, and so, the opportunities for structural failure will inevitably increase.

Nowadays, different tools are available to optimize any engineering solution, among 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.

The experimental techniques may be used to access the distribution of stresses or strains in the surface of diffuse materials. Imaging techniques used with structured or coherent illumination allow operating without contact to perform high resolution measurements. Likewise it is possible to obtain complex three-dimensional geometry of objects and analyzing its deformation in real time. With these techniques is thus possible to understand the behavior of structures and components under complex loading conditions even when they are constructed on new materials. These techniques have also shown themselves useful in the design and construction of structural monitoring systems. If the structural behavior of a component is previously known sensors can use to record continuously its stress level and prevent catastrophe situations, or, as well, to predict its service life.

Mário Augusto Pires Vaz was born in Bragança, northeast of Portugal, in August 1961. He studied Mechanical Engineering at the Faculty of Engineering of University of Porto (FEUP), where he received his PhD in Mechanical Engineering in 1995. He is Professor of the Department of Mechanical Engineering of FEUP and Director of the Laboratory of Optics and Experimental Mechanics of INEGI/FEUP. His main research interests are: Solid Mechanics, Experimental mechanics, laser metrology and, more recently, Experimental Biomechanics. He is member of the National committee for Experimental Mechanics and holds the position of president of the Portuguese Society of Biomechanics.

He is member of the following organizations: Portuguese Association of Experimental Stress Analysis (APAET), Portuguese Society of Biomechanics (SPB), Associação Portuguesa de Mecânica Teórica, Aplicada e Computacional (APMTAC), SPIE - The International Society for Optical Engineering, DYMAT-European association for the promotion of research into the dynamic behaviour of materials and its applications and is the Portuguese member of the European Society for Experimental Mechanics (EURASEM) and Society for Experimental Mechanics (SEM) councils. He was involved in more than two hundred papers published in international journals and conferences with peer review.

Provisional Conference Program. (The final is distributed on site)

Monday, June 25, 2012		
16:00-18:00	Registration at FEUP - Faculdade de Engenharia da Universidade do Porto, Rua Dr Roberto Frias, Porto (conference location)	
18:00-19:00	Welcome Cocktail at FEUP	
Tuesday, June 26, 2012		
08:00-09:00	Registration	
09:00-09:50	**Plenary Lecture: J. Komorowski, "The age for Reason"**	
	Session A: Structural Integrity - General	Session B: Laser technologies
10:00-10:20	M. Janardhana and P. Callus: "Life Management Aspects of Composite Airframe Structures in the ADF Environment"	F. Brenne, T. Niendorf, H.J. Maier: "Optimization of lattice structures manufactured by Selective Laser Melting"
10:20-10:40	M. Santos and J. Santos: "Structural damage evaluation using PZT sensors and guided waves"	K. Schmidtke, F. Palm, V. Holzinger, C. Emmelmann: "Laser additive manufacturing of ScalmalloyRP®: fracture and fatigue behaviour"
10:40-11:00	Y. Zhang, Y. Ding, C. Ye: "Calculation of the probability of failure on demand of redundant systems using Markov model"	D. Schnubel, N. Huber, M. Horstmann, P. Staron, T. Fischer:" Laser heating as approach to retard fatigue crack growth in aircraft aluminium structures"
11:00-11:20	Y.G. Matvienko: "Structural integrity assessment of components with defects and safety factors against fracture"	E. Wycisk, J. Kranz, C. Emmelmann: "Fatigue Strength of Light Weight Structures produced by Laser Additive Manufacturing in TiAl6V4"
11:20-11:40	**Coffee break**	
11:40-12:00	A. Pistek, J. Hlinka, I. Jebacek: "Design and structural testing of VUT experimental aircraft family"	M. Cabeza, G. Castro, P. Merino, G. Pena, M. Román: "Nd:YAG Laser cladding, a suitable tool to improve surface properties of a low nickel maraging steel"
		Session C: Residual stresses
12:00-12:20	J. Almeida, H. Alonso, P. Rocha: "Comparing the Extended Kalman Filter with an Hopfield Neural Network for on-line damage detection in Euler-Bernoulli beams"	M. E. Fitzpatrick, P. J. Bouchard, J. A. James: "Development of advanced techniques for determination of residual stresses"
12:20-12:40	P.J. Antunes, R.J. Guimarães, A.I. Vaz, J.C. Viana: "Structural health monitoring based on a global optimization approach"	D.F.O. Braga, V. Richter-Trummer, P.M.S.T. de Castro: "The use of contour method for evaluating residual stress fields in butt welded plates"
12:40-13:00	G. Qian, M. Niffenegger: "Probabilistic analysis of pipelines with corrosion defects by considering correlated input parameters based on FITNET FFS procedure"	
13:00-14:00	**Lunch**	

Provisional Conference Program. (The final is distributed on site)

14:00-14:50	**Plenary Lecture: M.A.P. Vaz, "Experimental techniques for stress/strain assessment and structural monitoring"**	
	Session D: Surface, films, layers, corrosion	Session E: Applications - I
15:00-15:20	J. M. Gómez de Salazar, M. I. Barrena, J. M. Vazquez, A. Soria: "Characterization of protective surface films formed on molten AM60 and AZ91 alloys in different atmospheres"	C. Almeida Santos, C. Oliveira Costa, J. Pereira Batista: "A Vision-based IEKF Full-Motion Estimation on Long-Deck Suspension Bridges"
15:20-15:40	M. Trueba, I. Ocaña, M.R. Elizalde, J.M. Martinez-Esnaola, M.T. Hernandez, M. Haverty, G. Xu, D. Pantuso: "Mechanical Characterization of Thin Films. Experiments and Modeling"	J. M. C. Maeiro, A. M. P. de Jesus, A. S. Ribeiro, A. L. L. Silva: "Fatigue crack propagation behaviour of a puddle iron under constant and variable amplitude loading"
15:40-16:00	C.M. Abreu, M.J. Cristóbal, R. Figueroa, G. Pena: "Evolution of corrosion resistance of AA7075 aluminium alloy after ion implantation by electrochemical impedance spectroscopy"	C. Thies, C. Albuquerque, S.M.O. Tavares, V. Richter-Trummer, M. A. V. de Figueiredo, P. M. S. T. de Castro: "A contribution to the characterization of the mechanical behavior of S355 structural steel"
16:00-16:20	**Coffee break**	
16:20-16:40	R. Losada, J. Miniño, X. R. Nóvoa1, M. C. Pérez, L. Mera, P. Vázquez: "Microstructure and corrosion properties of laser treated Aluminium-Nickel Bronze alloy"	F. Cunha, S. Rana, G. Vasconcelos, R. Fangueiro, S. Abreu: "Novel Retrofitting Solutions for Masonry Infill Walls Based on Braided Fibrous Materials"
16:40-17:00	R. Losada, X. R. Nóvoa, M. C. Pérez, L. Mera, S. Trillo, P. Vázquez: "The effect of different heat treatment on the wear and corrosion behavior of a Bronze Al-Ni alloy"	M.M.C. Araújo, A.B. Silva, G.N.D. de Carvalho: "Locating and Quantifying Damages in a 3-D Frame Using Residual Error Method"
17:00-17:20	R. Losada, P. Merino, X. R. Nóvoa1 and M. C. Pérez: "Influence of two ASTM surface finishings in the corrosion behaviour of stainless steels AISI 304 and AISI 436"	S. Rana, K. Rosado, R. Fangueiro: "Development of Braided Composite Rods for Structural Health Monitoring"
17:20-17:40	C. Abreu, M.J. Cristóbal, D. Gesto, I. De Labra, G. Pena, P. Rey: "An investigation on the electrochemical behaviour of a Friction Stir Processed Mg-Al-Mn Alloy"	
18:30	**Transportation from FEUP to Port wine cellars in Vila Nova de Gaia**	
19:00-20:00	**Visit to Port wine cellars, in Vila Nova de Gaia**	
20:00-22:00	**Conference Dinner**	

Provisional Conference Program. (The final is distributed on site)

	Wednesday, June 27	
09:00-09:50	**Plenary Lecture: C. Dalle Donne, "Lighter, faster, greener - additive layer manufacturing of aerospace structures"**	
	Session F: Composites	Session G: Fatigue
10:00-10:20	H. Mata, R. Natal Jorge, A. D. Santos, M.P.L. Parente, R. A. F. Valente, A.A. Fernandes: "Study of Sandwich Panels with Metal Foam Core for Forming Process"	W. Zhuang, Q. Liu, C. Smith: "Experimental investigation of initial flaws in aircraft 2024-T3 thin sheet"
10:20-10:40	H. Silva, C. Capela, J.A.M. Ferreira, J.D.M. Costa: "Assessment of the interlaminar fracture toughness on nano-filled epoxy/glass fibre composites"	J. Bierbaum, P. Horst: "Numerical simulation of crack propagation in buckling aluminum panels"
10:40-11:00	J.M. Silva, P. Fael, A. Menezes, J. Morgado: "Mechanical behavior of composite materials with enhanced energy absorption properties"	K. Langer, T.J. Spradlin: "Investigation of Fatigue Scatter in Laser Peened Aluminum Test Coupons"
11:00-11:20	M. Benachour, F.Z. Seriari, M. Benguediab, N. Benachour: "Effect of composite patch in repaired plate on FCG under different tempered situation"	P.M.G.P. Moreira, P.M.S.T. de Castro: "AA2024-T3 FSW tailor welded blanks: fatigue crack growth behavior"
11:20-11:40	**Coffee break**	
11:40-12:00	P.P. Camanho, A. Turon, P. Portela, G. Sinnema: "Damage tolerance verification of composite spacecraft structures"	L. Reis, B. Li, V. Anes, M. de Freitas: "Evaluation of multiaxial fatigue loading paths in different shear stress spaces"
12:00-12:20	M.H. Shamsudin and C.B. York: "Buckling response of hygro-thermally curvature-stable laminate with extension-twisting coupling"	J. Doucet, X. Zhang, P.E. Irving: "Fatigue modelling of aluminium plates reinforced with bonded fibre metal laminates"
12:20-12:40	M.V. C. Fernández, M. F. S. F. de Moura, L. F. M. da Silva, A.T. Marques: "Mixed Mode behavior for composite bonded joints using the SLB test"	H.F.S.G. Pereira, J.A.F.O. Correia, A.M.P. de Jesus: "A discussion on fracture mechanics crack growth-based fatigue life prediction applied to a notched detail"
12:40-13:00		T.J. Spradlin, K. Langer: "Use of Laser Peening for Fatigue Life Extension of Pre-fatigued Components"
13:00-14:00	**Lunch**	

Provisional Conference Program. (The final is distributed on site)

	Session H: Applications - II	Session I: Biomechanics
14:00-14:20	M.S. Santos, R.F. Martins, P.P. Silva, A.R. Mateus: "Structural performance of a lifeboat craft under the application of static and dynamic loadings"	F.A.M. Pereira, J.J.L. Morais, N. Dourado, M.F.S.F. de Moura, M.I.R. Dias:"Cohesive zone modeling of the DCB test in cortical bone tissue"
14:20-14:40	E.H.I.F. Vieira, R.F. Martins, P.P. da Silva: "Application of alternative lightweight structures to support an helicopter flight deck"	A.C. Vale, J. Faustino, L.G.Reis, A. Lopes, B. Vidal, J. Monteiro, J.E. Fonseca, H. Canhão, M.F. Vaz: "Effects of the Shear Strain Rate on the Torsion of Trabecular Bone"
14:40-15:00	G. Vallone, C. Sbarufatti, A. Manes, M. Giglio: "Estimation of structural damage on Helicopter tail boom in case of harsh landing events"	F.A.M. Pereira, J.J.L. Morais, N. Dourado, M.F.S.F. de Moura, M.I.R. Dias: "Fracture characterization of cortical bone tissue under mode II loading using the end loaded split and the end notched flexure tests"
15:00-15:20	I.C. Urízsar-Aldaca, M.V. Biezma, J.M. Terrés-Nicoli: "Involved variables for de assessment of the coupled wind induced fatigue behavior of exposed slender structures"	C. Palma, A.C. Vale, P.M. Amaral, L. G. Rosa, A. Lopes, J. Monteiro, J.E. Fonseca, H. Canhão, M.F. Vaz: "Compressive Fatigue Tests on Trabecular Bone"
15:20-15:40	A. Cernescu, L. Marsavina, I. Dumitru: "Structural integrity assessment for a component of the bucket-wheel excavator"	P.A.F. Rodrigues, M.J.O. Geraldes, N.J.R. Belino, C.A. Ferraz, S.I.V. Sousa: "The use of nanomaterials in the control and prevention of Legionella bacteria"
15:40-16:00	**Coffee break**	
16:00-16:20	T. Doca, F.M. Andrade Pires, J.M.A. César de Sá: "Structural integrity of tires"	Visits to Laboratories
16:20-16:40	R. Mandard, S. Baïz, J.-F. Witz, X. Boidin, Y. Desplanques, J. Fabis, R. Ortiz, E. Deletombe: "Turbomachines blades integrity and seal materials interactions - Dynamic experimental analyses"	
16:40-17:00	S.M.O. Tavares, T. dos Santos: "Defects Detection in Aeronautical Structures joined by Friction Stir Welding"	
17:00-17:20	D. Peixoto, L.A. Ferreira, P.M.S.T. de Castro: "Wheel/rail contact: fatigue behaviour"	
17:20-17:40	L. Reis, P. Santos, B. Li and M. de Freitas: "Wheel/rail contact fatigue: theoretical and experimental analysis"	

Provisional Conference Program. (The final is distributed on site)

	Thursday, June 28	
09:00-09:50	**Plenary lecture: C. Rodopoulos, "Fatigue damage discrepancies and the multiple stages of the similitude concept"**	
	Session J: Joining technologies	Session K: Structural Mechanics and numerical modeling
10:00-10:20	C. Lauter, M. Sarrazin, T. Troester: "Joining technologies for hybrid materials consisting of sheet metal and carbon fibre reinforced plastics"	S. Moreira, J. Belinha, L.M.J.S. Dinis, R.M. Natal Jorge: "The enriched natural neighbour radial point interpolation method for the analysis of crack tip stress fields"
10:20-10:40	W. Sun, M. B. Mohammed, L. Xu, T. H. Hyde, D. G. McCartney and S. B. Leen: "Evaluation of modelling capability of KPA welding fabrication of thin structures of Titanium alloy"	J. Monteiro, M.P.L. Parente, R.M. Natal Jorge, A.A. Fernandes: "Use of Isogeometric Analysis to simulate a sheet metal forming operation using the Finite Element code LS-DYNA"
10:40-11:00	S. Ladisch, M. Rinker, B. Teich, R. Schäuble: "A novel test method for durability evaluation of an adhesively bonded joint between CFRP and CFRP sandwich components under surface loading"	F.J.P. Reis, F.M. Andrade Pires: "Coupled-Multi Scale Models: Advantages and limitations"
11:00-11:20	R.D.S.G. Campilho, M.D. Banea, L.F.M. da Silva: "Accuracy of adhesive joint strength predictions by finite element analyses"	N. Mukunthamani, M.P.L. Parente, A.A. Fernandes, R.M. Natal Jorge: "Application of Finite element formulation to solid-shell structures for the analysis of time reduction"
11:20-11:40	**Coffee break**	
11:40-12:00	P.F.P. Afonso, R.D.S.G. Campilho, A.M.G. Pinto: "Study and optimization of the single-lap and T-peel joints using the finite element method"	S.H.Wu, F.M.A. Pires, A.D. Santos, A. Barata da Rocha: "A primal closest point projection algorithm for Magnesium alloys"
12:00-12:20	F.J.P. Chaves, L.F.M. da Silva, M.F.S.F. de Moura, D. Dillard: "Mixed-mode fracture toughness determination using non-conventional techniques"	N. Allahverdizadeh, A. Manes, M. Giglio: "Application of CDM models for the simulation of the mechanical behavior of Ti-6Al-4V titanium alloy under different loading conditions"
12:20-12:40	M.D. Banea, L.F.M. da Silva, R.D.S.G. Campilho: "Mechanical Characterization of a High Temperature Epoxy Adhesive "	A. Tavangari, M.T. Kamali: "Analysis of elastic fields in an isotropic medium containing a penny-shaped crack by the Ritz method"
12:40-13:00	E.R. Libanio, R.R. Rodriguez, A. Silva, M.A.V. de Figueiredo, P.M.G.P. Moreira: "FSW - Most influent welding parameters and their interactions on joints mechanical properties"	S.M. Zahrai, M. Pirdavari, H.M. Farahani: "Evaluation of hysteretic behavior of eccentrically braced frames with zipper-strut upgrade"
13:00-14:00	**Farewell Lunch**	
Afternoon	**Tour of the Minho region**	

Abstracts

Life Management Aspects of Composite Airframe Structures in the ADF Environment

Madabhushi Janardhana[1] and Paul Callus[2]

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Abstract.

In both military and commercial aviation, a focused life management program for airframe structures is required once the aircraft start operating in service. The discipline of holistic airframe management is commonly known as Aircraft Structural Integrity (ASI) management. The increased use of composite structures in the primary and secondary structure of Military aircraft has created a need to consider the life management (LM) aspects that are specific to these structures. This paper provides a brief review of current state addressing the deficiencies and limitations in regulations and standards dealing with LM of composite structures – as relevant to airframe applications. In providing this review, this paper also briefly discusses numerous damage mechanisms and defect characterization with a view to address their relevance to LM of composite structures. A future program plan on Damage and Life Management (D-LM) approaches for composite structures is briefly outlined.

Keywords: Airframe Structural Integrity, Composite Structures, Life management

Structural damage evaluation using PZT sensors and guided waves

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Abstract

Vibration-based techniques for structural health monitoring (SHM) have been extensively studied for several years in order to evaluate damages, which usually produce changes in the vibrational characteristics of the structure, such as natural frequencies, mode shapes and modal damping. Recently, damage detection through ultrasonic guided waves, such as Lamb waves, has been gained increasing importance due to the possibility of inspecting large structures. Once excited, the Lamb waves can propagate all over considerable distances. Thus, a receiver positioned on the structure at a remote position can collect the propagation signals observed along with the path between transmitter and receiver, providing information about eventual surface defects or internal cracks. The generation of Lamb waves by conventional transducers has some limitations because they are relatively large and expensive. An emerging technique based on piezoelectric lead zirconate titanate (PZT) sensors has the potential to improve significantly the SHM. These sensors are small, lightweight, inexpensive, and can be produced in different geometries. They can be bonded on the structures surface, mounted inside built-in structures and can even be embedded between the structural and non-structural layers of a complete construction.

This work deals with the evaluation of the applicability of bonded PZT sensors for the detection and classification of different artificial defects in aluminum plates as well as impact defects in fiber glass composite plates. First, the sensors have been designed and bonded on different plates. It was observed that the experimental behavior of sensors is according to theoretical predictions. Fundamental symmetrical (S_0) and anti-symmetrical (A_0) modes were identified in our experiments. These modes were proved by solving the Rayleigh-Lamb frequency equations. Some holes and slits with different dimensions were drilled in the aluminum plates and the laminate composites were impacted with different energy levels. Using a pitch and catch configuration, the signals have been collected after interaction with defects. Three different approaches of signal processing techniques have been used for defect detection: time, frequency and integrated time-frequency analysis. Simple amplitude measurements were accomplished in time domain analysis. In the frequency domain, the use of the Fast Fourier Transform (FFT) allowed the detection of deviations from the original benchmark spectrum. The time-frequency analysis, which combines time and frequency information, has given rise to the so-called spectrogram, based on two different approaches: Short-time Fourier Transform (STFT) and Wavelet Transform (WT). The best results are provided by the time domain method, probably due to the high tuned behavior of the PZT sensors, which hide small spectrum variations. Based on the experimental measurements, it is possible to establish empirical relations in an attempt to describe signal amplitude behavior with defect dimensions. The presented results, due to their empirical character need to be confirmed with other experimental configurations, namely: plate dimensions, type of material, defect geometries or coupling. However, it was demonstrated the applicability of PZT sensors, when defect evaluation in plates is demanded.

Calculation of the Probability of Failure on Demand of Redundant Systems using Markov Model

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Abstract

It is necessary to calculate the "Probability of Failure on Demand" (PFD) and "Probability of Failure of Safety" (PFS) for the assessment of the "Safety Integrity Level" (SIL) of a safety instrumented system (SIS) in the international standard IEC 61508 [1]. To fulfill the high safety and availability requirements redundant channels are often used, which are normally homogeneous. Whereas, in order to minimize the potential common cause failures (CCF) for very high safety requirements (e.g. SIL4) it may be advisable to build up a heterogeneous system with different hardware/software platforms. For such type of heterogeneous systems the calculation of the PFD is a challenge because the failure rates of the particular channels are different in general and no formulas are included in the standard.

Within the scope of this work, the physical block diagram and the voting diagram for 2oo3 redundant system are introduced, then based on them, the Markov-model method is used to simulate these redundant systems, including both the homogeneous and the heterogeneous systems.

Keywords: Functional safety, redundant system, probability of failure on demand, Markov model

Structural Integrity Assessment of Components with Defects and Safety Factors against Fracture

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Abstract

The defect assessment methods pursue two different philosophies, which can be designated as failure assessment diagram and crack driving force. To substantiate the structural integrity and acceptable states of damaged components, safety factors against fracture and plastic collapse are included in basic equations of fracture mechanics and fatigue. The safety factors against fracture are calculated by demanding that the applied critical stress should not be less than the yield stress of material for a component with a crack or a notch of the acceptable size. Basic equations have been presented to calculate the safety factor against fracture for critical values of the stress intensity factor, crack tip opening displacement, the J-integral and the failure assessment diagram as well as to estimate an acceptable (safe) region for an engineering component with a crack- or notch-like defect of the acceptable size. Structural integrity assessment of the engineering components damaged by crack- or notch-like defects is discussed from view point of the failure assessment diagram. The methodology of the criterion of average stress in the fracture process zone ahead of the crack/notch was employed to develop failure assessment diagrams for a solid with a finite crack/U-notch under mode I loading. The local critical stress in the fracture process zone is treated according to von Mises yield criterion as a property of both the yield stress and the T- stress which was introduced into the criterion to quantify local constraint in different geometries and type of loading. It was shown that the safety factor against fracture for a notch-like defect is a function of the yield stress as well as the elastic stress concentration factor and the safety factor against plastic collapse. For the special case of a notch the failure assessment diagrams are transferred to the failure assessment diagram for component with a sharp crack, and the safety factor becomes the safety factor against fracture of cracked component. The methodology of the failure assessment diagram has been employed for the structural integrity analysis and assessment of acceptable sizes of throw-thickness notch in a plate under tension and surface longitudinal notch-like defects in a pressure vessel.

Design and structural testing of VUT experimental aircraft family

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Abstract The family of experimental aircraft created at Brno University of Technology represents new approach to development in several fields, and combines them together. The paper will provide information on development of aircraft at the university environment. Detailed information on design and structural testing of VUT 001 Marabu will be given, with particular attention on testing of structures with large deformations and testing of composite structures under increased temperature. Information on successors to Marabu aircraft will be provided as well, in particular VUT 051 Ray and VUT 061 TURBO. VUT family of aircraft has combined structure with fuselage from composite materials and all-metal wing and tail unit. Major purpose of the aircraft is to provide platform for experimental validation of performance for newly developed engines and equipment.

Comparing the Extended Kalman Filter with an Hopfield Neural Network for on-line damage detection in Euler-Bernoulli beams

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Abstract: The aim of this contribution is to compare two methods for on-line damage detection in Euler-Bernoulli beams. The first method is based on the Extended Kalman Filter (EKF) [1] and the second method is based on an Hopfield Neural Network (HNN) [2]. Damage is represented by a change in some of the beam parameters and both methods track this change.

The free vibration of a beam with length L, simply-supported in both ends, has been considered and described by $\mu\frac{\partial^2}{\partial t^2}w(t,x)+c\frac{\partial}{\partial t}w(t,x)+EI\frac{\partial^4}{\partial x^4}w(t,x)=0$. In order to apply the EKF, this equation is rewritten as a first order model as explained next. The separation of variables method is applied to the beam deflections $w(t,x)=f(t)g(x)$, where $g(x)$ is taken as $g(x)=sin(\frac{\pi}{L}x)$ and $f(t)$ is the solution of $f''(t)+\frac{c}{\mu}f'(t)+\frac{EI}{\mu}f(t)=0$ with initial conditions $f(0)=\gamma_0$, $f'(0)=\gamma_1$. This corresponds to considering $w(0,x)=\gamma_0\,sin(\frac{\pi}{L}x)$ and $\frac{\partial}{\partial t}w(0,x)=\gamma_1\,sin(\frac{\pi}{L}x)$. Taking the spatial discretization $\overline{W}$ of $g(x)$, the evolution of the spatial discretization of $w(t,x)$, given by $W(t)=f(t)\overline{W}$, can then be described by means of a first order model $X'(t)=F(\theta)X(t)$, with state vector $X(t)=(f(t)\overline{W},f'(t)\overline{W})$ and parameter vector $\theta=(\theta_1=\frac{EI}{\mu},\theta_2=\frac{c}{\mu})$. In order to apply the HNN, this first order model is rewritten in the form $y(t)=A(t)\theta$, where $y(t)$ and $A(t)$ are a certain vector and a certain matrix, respectively, computed from the system data.

Figure 1 presents an example of the obtained results for a damage simulated at 0.5 seconds by a change in θ. As can be seen, both methods track the change and thus allow for damage detection. Complete results, under various conditions, will be presented in the full paper.

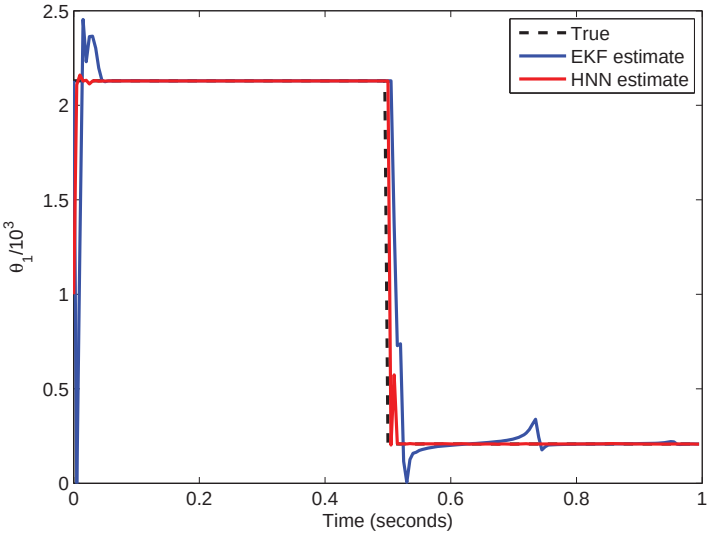

Figure 1: EKF and HNN on-line damage detection.

Acknowledgements:

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Structural Health Monitoring Based on a Global Optimization Approach

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Abstract

SHM-Structural Health Monitoring of critical parts is gradually assuming a relevant role in several engineering fields such as civil, aeronautical and aerospatial. For the particular case of vibration-based SHM techniques, variations in the structure's dynamic response with respect to a healthy baseline (resonance frequencies, mode-shapes and modal damping) are monitored in order to detect the presence of structural damage. Several SHM techniques are able of determining the presence of damage. However, the location and damage severity estimations are variables more difficult to assess. In fact, for the SHM community, this is a very important research field. Critical Materials, of years to this part, is focusing its work in the development of SHM algorithms based on the combination of information retrieved from virtual models (FE-Finite Element) with dynamic data obtained from components in service.

In this work, a new SHM approach based on global optimization techniques is presented, combining data retrieved from FE models and experimental data. This method is able of, simultaneously, locating, determining the type of damage (stiffness, mass, damping) and outputting its severity (size and variation in material properties). This method demands automated pre/post-processing operations of dynamic FE models, using Abaqus scripting capabilities, and continuous data exchange between Abaqus platform and the external global optimization module. The proposed approach results in a closed loop optimization process, with automated local variation of material and structural properties, driven through the considered objective function.

In order to discuss the potentiality of the proposed method several case studies are presented and discussed.

Probabilistic analysis of pipelines with corrosion defects by considering correlated input parameters based on FITNET FFS procedure

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Abstract

The paper gives a review on the probabilistic assessment for pipeline containing defects. A probabilistic methodology considering the correlations between the input variables for the failure probability evaluation of corroding pipelines based on the FITNET FFS procedure is developed. The comparison of the failure pressure determined by both deterministic and probabilistic methods shows that even for a high safety factor, the deterministic method may predict nonconservative results. FITNET FFS procedure predicts a similar probability to that given by the Shell-92 model. The sensitivity analysis of both the uncertainty of the variables and the underlying model shows that the corrosion depth has the most significant contribution to the pipeline failure at an inspection interval of 8 years. If the correlations between the initial defect depth, the initial defect length and the operating pressure for an individual defect are not considered, the prediction results can be nonconservative. In case of multiple defects, the correlation of the operating pressure, the initial defect depth and material ultimate tensile strength at the location of different defects has a larger impact on the failure probability than the others at different defects.

Optimization of lattice structures manufactured by Selective Laser Melting

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**Corresponding author, e-mail: florian.brenne@uni-paderborn.de*

Abstract

In light of shortage of resources, the design and analysis of light-weight structures become increasingly important. Cellular metallic materials produced by direct manufacturing tools are promising candidates to fulfill the upcoming requirements in terms of design flexibility and high specific strengths. Recent studies mainly focus on monotonic mechanical properties of such structures, especially under compressive load. So far, local deformation mechanisms under different loading scenarios have received little attention despite the relevance for actual applications.

Therefore, the objective of the current study was to address the deformation behavior of a lattice structure produced by selective laser melting. A comprehensive in-situ approach was applied using electron back scatter diffraction, finite elements method (FEM) and digital image correlation (DIC). Samples of stainless steel and titanium alloy were heat-treated and tested under monotonic and cyclic loading. Results showed that FEM and DIC are capable of describing the local deformation behavior and detecting failure at an early stage of deformation. The study contributes to understanding the mechanical properties and clarifies the role of local deformation mechanisms. The outcomes allow for subsequent optimization of geometry to design optimized load-adapted structures.

Laser Additive Manufacturing of ScalmalloyRP®: Fracture and Fatigue Behaviour

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Abstract

Modified aluminium alloys containing scandium and magnesium, called ScalmalloyRP®, built up by powder bed based laser additive manufacturing (PB LAM) offer great potential for aerospace applications. ScalmalloyRP® provides an excellent combination of static strength and toughness, but a full material analysis including fracture and fatigue behaviour is essential to validate that it meets the high requirements to become an allowable material for structural aerospace parts. Fracture mechanical characteristics consisting of fracture toughness testing, high cycle fatigue and crack growth behaviour were therefore investigated and are presented in this paper. Samples for each test were manufactured in two different directions (0° and 90°) and tested after artificial aging (4 hours at 325°C). Available alternatives in material choice and manufacturing process are either milling of high strength 7xxx Al-alloys or LAM of medium strength Al-alloys containing silicon and magnesium. Fracture toughness of ScalmalloyRP® was determined for Mode I resulting in KIC values. Both high cycle fatigue (HCF) and crack growth propagation were tested at load ratio R=0.1 whereas crack growth behaviour was additionally tested at a load ratio of R=0.7 to avoid crack closure effects. All investigations show an outstanding material behaviour. Fracture toughness tests result in values presented as combination of yield strength against achievable KIC per aluminium series in Figure 1 a.). A mean value of 39 MPaÖm at yield strengths between 500MPa and 515MPa was reached. High cycle fatigue behaviour at load ratio R=0.1 ,is slightly superior to HCF-behaviour of standard high strength 7075 plate material. The S N curves (maximum stress against number of cycles to failure) reveal a run out at 3x107cycles at a maximum stress level of 300MPa, as can be seen in Figure 1 b.). Fatigue-crack growth rate investigations show slow, stable, crack growth for both load ratios investigated (R=0.1 and R=0.7), when compared with high strength 7075 plate material. The results of the testing that was performed demonstrate acceptable fracture and fatigue properties can be achieved with ScalmalloyRP®.

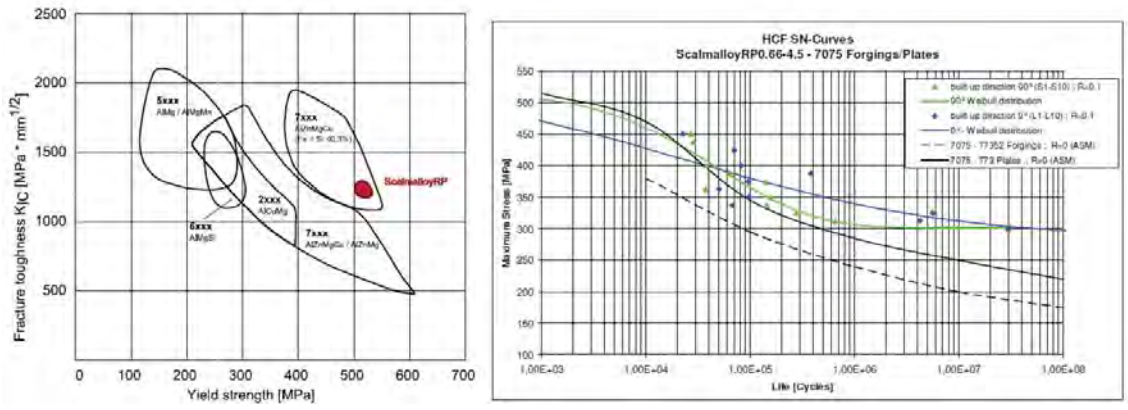

Figure 1 *Material behaviour ScalmalloyRP® a.) Fracture toughness KIC b.) S-N curve*

Laser heating as approach to retard fatigue crack growth in aircraft aluminium structures

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[2]*Institute of Materials Research, Materials Physics, Helmholtz-Zentrum Geesthacht, 21502 Geesthacht, Germany*

Abstract While normally the formation of thermally induced residual stresses is seen mainly as detrimental side effect from production processes like welding or casting, during the last decades some researchers also used the well-directed introduction of thermal residual stresses as tool to retard fatigue crack growth. In the presented study, a defocused laser is used to create a heating line on AA2198-T8 C(T)100 specimens in order to modify the residual stress state. The presented results including thermocouple measurements, residual stress measurements and fatigue crack growth tests show that it is possible to retard fatigue crack growth via laser heating. As next step a quantitative numerical prediction methodology for the resulting fatigue crack growth is developed and validated stepwise on basis of the experimental results. The developed approach couples numerical process simulations for the prediction of the residual stresses with subsequent numerical fracture mechanics analyses. The validated prediction methodology is then used to study the effect of the heating line position on the fatigue crack growth. In conclusion, it is demonstrated that laser heating has the potential to be employed for fatigue crack growth retardation in aircraft aluminium structures.

Fatigue Strength of Light Weight Structures produced by Laser Additive Manufacturing in TiAl6V4

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Abstract

Layer wise manufacturing technologies such as Laser Additive Manufacturing (LAM) gain increasing importance for light weight applications in the automotive and aircraft industry. In these applications TiAl6V4 is of highest interest due to its corrosion resistance and specific strength. Most important the design freedom of LAM allows innovative approaches for light weight structures, such as topology optimization, bionic-design and lattice structures. These approaches for individual, load-adapted designs result in highly complex geometries with hollow and for conventional tooling and surface finishing inaccessible or hardly accessible geometries. Therefore the surfaces of LAM light weight parts mainly remain in their production state with roughness of 10 µm – 20 µm Ra. However the growing number of LAM parts exposed to complex and dynamic load cases bare the need for reduction of surface roughness to ensure high fatigue strength and therefore have to be improved by geometrically undefined surface treatments such as shot peening, polishing, etching, etc.

This paper presents an analysis of the fatigue behavior of complex LAM parts as they are present in above mentioned applications. Current research neglects LAM inherent design features such as thin wall thicknesses, hollow structures and unfinished surfaces. Therefore the investigations are based on a broader view analyzing geometrically undefined surface treatments and their effect on the fatigue strength of LAM TiAl6V4. The influence of the penning process on LAM TiAl6V4 is analyzed and adequate specimens are tested in high cycle fatigue to ensure predictions of the fatigue limit of light weight LAM structures. With peening results showing a significant reduction of surface roughness to less than 1.5 µm Ra and a resulting fatigue strength improvement of more than 100%, LAM light weight structures are able to gain an even greater share of applications in the aircraft and automotive industry.

Nd:YAG Laser cladding, a suitable tool to improve surface properties of a low nickel maraging steel

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Abstract

Maraging steels (MS) are low-carbon ultrahigh-strength alloys whose mechanical properties are achieved due to a fine precipitation of intermetallic compounds obtained after an age hardening treatment. Because they offer one of the bests combinations of ultrahigh yield and tensile strength, ductility and fracture toughness of any ferrous materials, are usually applied in aircraft landing gears, rocket cases, drive shafts, casting dies and structural parts. Nevertheless the MS show a remarkable disadvantage, their price, caused by the great amount of alloying elements, the great purity, achieved by vacuum melting, and the thermal treatments that are required to get the intermetallic precipitation. This makes that repair and surface improvement processes become interesting to increase the service life of parts made in this type of alloys, contributing to amortize the investment made on them. This could be carried out with many disposable technics, but the low dilution derived, the excellent process control, the high precission and the sharply concentrated heat input, among other notable characteristics, allows laser cladding turn into a suitable tool to succeed in this kind of processes.

In this work, the modification of the surface properties of base material, the age hardened low nickel (14%) maraging steel, after being processed by means of laser cladding, and how do the changes induced by this surface processing affects the final properties of the MS, which are obtained after submitting laser processed MS to a new aging heat treatment, are studied. TiN particles were used as reinforcement and Nd:YAG laser parameters were optimized to obtain a free-defect overlay.

Visible light and scanning electron microscopy were used to define the microstructure and, together with mechanical profilometry, the quality of the obtained overlays. Vickers hardness and pin-on-disk wear tests were performed in order to characterize their mechanical behaviour.

After laser cladding, the affected zones of the MS are clearly softened even hardness values of some zones of the molten pool and the surface wear resistance are clearly higher than those of the base MS. Nevertheless, after the final aging treatment, the hardness of the heat affected zones is recovered, the hardness of the molten pool increases strongly with respect to the aged MS and the wear resistance gets seriously improved.

Development of advanced techniques for determination of residual stresses

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Abstract

Knowledge of residual stresses is key to understanding the structural integrity of safety-critical components and systems. Residual stresses can influence the initiation and growth of fatigue cracks, and influence processes such as creep crack growth at high temperature.

Accurate measurement of residual stresses is therefore required for input to structural integrity calculations. This paper will present recent developments in two complementary techniques: neutron diffraction, and the contour method.

Neutron diffraction can measure stresses deep within complex components, but for complex geometries the set-up time can be considerable and the experimental execution can be difficult. A software simulation system for strain scanning – SScanSS – has been developed whereby a virtual model of the sample is prepared and, by locating the real sample on the instrument by determining fiducial points on its surface, rapid measurement set-up and accurate measurement location is achieved.

The contour method is a relatively new technique for residual stress measurement, where a sample is cut in half and the relaxed surface contours are measured to allow calculation of the pre-existing residual stress. The method has the advantage of providing a complete cross-sectional measurement of the stress normal to the cut surface. There are challenges in identifying the correct cut parameters and the data analysis for smoothing the measured contour.

The paper will present results obtained using these methods from weld residual stresses in applications for the aerospace and nuclear power industries.

The Use of Contour Method for Evaluating Residual Stress Fields in Butt Welded Plates

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Abstract

Residual stresses play a critical role in several mechanical or structural failure mechanisms, such as fatigue or fracture, just to name a few. The contour method, invented by Prime [1], provides an inexpensive albeit time consuming technique for full field residual stress measurement. In order to avoid residual stress associated problems, post weld treatments may be implemented. In this work measurements obtained with the contour method of both an untreated welded plate specimen as well as a heavy rolled similar specimen are presented. It was possible to observe that not only the nominal values of the residual stresses are lower but also their signal was inverted, i.e. the areas subjected to compression became subjected to tension and the zones subjected to tension became subjected to compression. This fact will have an obvious crack propagation effect and this will have to be considered in the project of components or structures which will be subjected to this treatment.

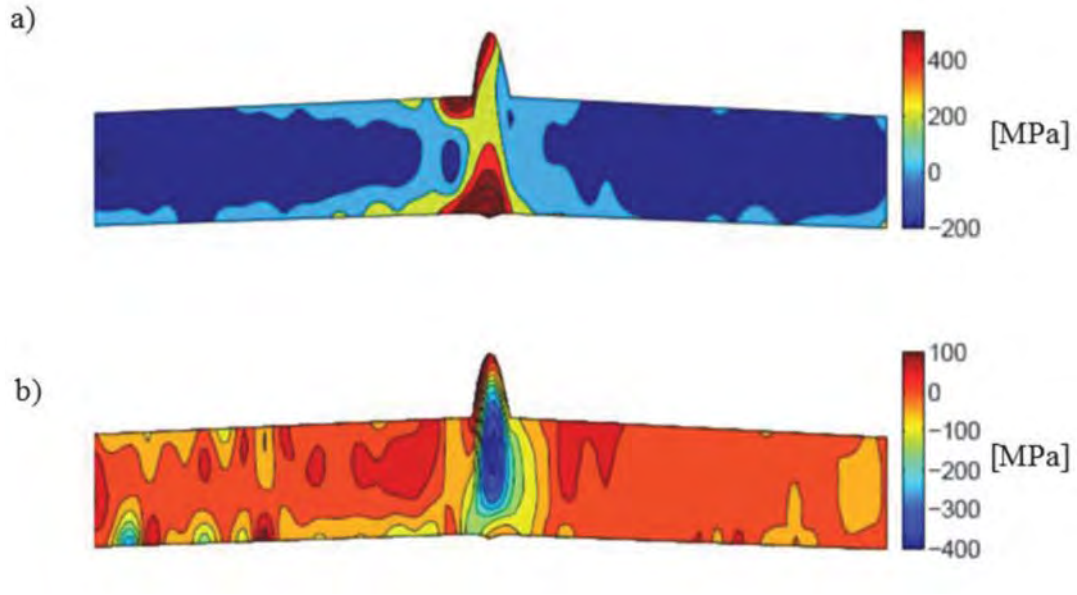

Figure 1 – *Residual Stress Measured Using the Contour Method (a – Unrolled Specimen, b – Rolled Specimen)*

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Characterization of protective surface films formed on molten AM60 and AZ91 alloys in different atmospheres

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Abstract

Magnesium and its alloys have excellent physical and mechanical properties for a number of applications. However, magnesium is a very active element, and it has extremely high affinity with oxygen and high vapor pressure of molten magnesium, it is essential to take some measures to prevent magnesium from oxidizing and burning during melting and processing. Small additions of some gases as fluorine-containing compounds have been suggested for this application. The most commonly used additive in the magnesium industry today is SF_6 but it is now known to be a strong greenhouse gas. Several alternatives have been identified and tested. 1,1,1,2-tetrafluoruethane (HFC-134a) has been shown as the most attractive to replacement for SF_6.

AM60 and AZ91 alloys were used in the study and the alloys were melted in an induction furnace under a mixture of HFC-134 and a diluents gas of N_2 technical or N_2 ultra pure that were controlled by mass flow meters. The morphologies and compositions of the surface films formed during the melt processes at different conditions were investigated and analyzed by means SEM, XRD and XPS. The morphologies and compositions of the surface films formed on AZ91 and AM60 alloys melt under the atmosphere of HFC134/N_2 cover gas mixtures are different (Figures 1 and 2), which depend on the concentration cover gas mixtures, the melt temperature and the matrix component.

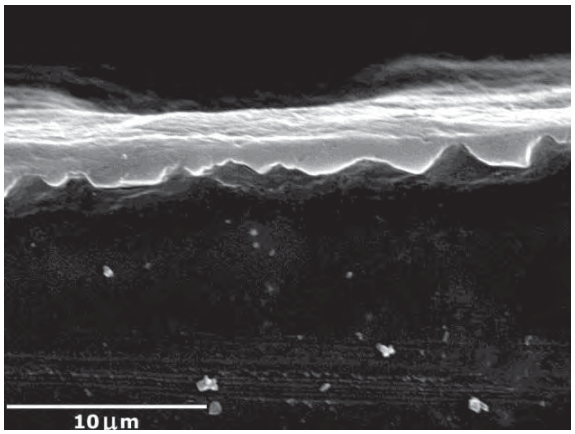

Figure 1 *– SEM image of cross-section sample of AM60*

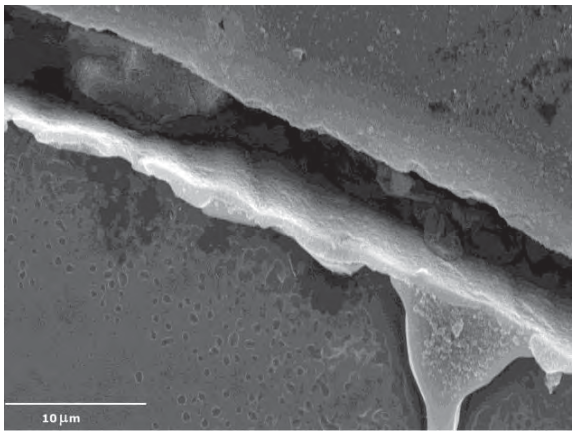

Figure 2 *– SEM image of cross-section sample of AZ91*

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Mechanical Characterization of Thin Films. Experiments and Modeling

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Abstract

The miniaturization process, driving force in Microelectronics, leads to the introduction of new materials for each generation of microprocessors. These materials, in form of thin or very thin films in the integrated circuits are subjected to high stresses (both during the fabrication process and in service) that may compromise the reliability of the device. Besides, the mechanical properties of a thin film are known to differ from the measured in the bulk of the same material. As a consequence it is key for the development of the industry the ability to characterize the mechanical behavior of the new materials taking into account the size effects.

In this contribution an experimental technique (consisting on the FIB machining and testing of microbeams) for the characterization of the elastic-plastic behavior of thin films is presented. The technique can be used for the fracture characterization of brittle (ceramics) and ductile (Cu) thin films.

Different beam geometries machined from films from various thicknesses (form 0.3 to 4 μm have been tested and the experimental results have been compared with FE models used to understand the outcome and to extract quantitative information on the intrinsic properties of the films.

Evolution of corrosion resistance of AA7075 aluminium alloy after ion implantation by electrochemical impedance spectroscopy

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Abstract

High strength aluminium alloys are widely employed in aerospace industry due to their attractive properties such as high specific strength, ductility, toughness and fatigue resistance. Despite the formation of an alumina layer on their surface, It is well known, that corrosion resistance is dependent of the intermetallics constituent particles that present a strong galvanic coupling with the matrix [1,2] , therefore these alloys are sensitive to pitting, intergranular corrosion, exfoliation and stress corrosion cracking.. Moreover, the susceptibility of these alloys is also affected by the aging treatments that modify their microstructure to obtain the optimal mechanical properties [3].

Different surface modification techniques can be used for improving their corrosion resistance such as chemical conversion coatings, anodizing, continuous organic coatings or the use of inhibitors to modify the properties of the medium [4]. Ion implantation is another powerful technique to modified the surface and improve the corrosion and tribological properties of metals without changing or sacrificing the bulk properties. N implantation has shown to improve the corrosion resistance of aluminum and its alloys 5. However, this effect is not clearly established since it is highly dependent on the implantation conditions, the selected alloy and its ageing treatment and the environment.

In this paper we analyze the effect of N implantation (at saturation dose) on the corrosion behavior of an AA7075 aluminum alloy. In order to determine the influence of ageing treatment, two tempers have been studied: T6 and T73. Electrochemical impedance evolution over 72h of immersion in 0.5 M NaCl was monitored to compare the evolution of corrosion at the surface.

The results show an increase of the surface impedance in the N-implanted samples at all considered times and for both tempers, being higher for the T6 samples. This improvement in corrosion resistance and the detected differences between T6 and T73 samples, is correlated to the composition and structure of the passive films formed on the surface and the different microstructure of the tempers.

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Microstructure and corrosion properties of laser treated Aluminium-Nickel Bronze alloy

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Abstract

Aluminium-Nickel bronze alloys are widely used in marine applications, specially for making marine propellers. Alloys containing 9-12 wt% Al, with additions up to 6 wt% of Fe and/or Ni represent one of the most important groups of commercial aluminium bronzes. The corrosion resistance of those alloys is rather variable, which has been attributed to their complex microstructure, dependent on the chemical composition and the thermal history during the casting process.

Laser surface melting (LSM) is a common resistance method of surface modification in the field of material processing for improving to corrosion and erosion. Focussed laser energy is used to melt the near surface region aiming at improving the surface dependent properties[1].

Corrosion process is a surface phenomenon that can be minimized by appropriate modification of the surface composition[2,3]. In the present work, the influence of different LSM treatments in the corrosion resistance of an Aluminium-Nickel bronze alloy in chloride solutions was analyzed. Cyclic Voltammetry and Electrochemical Impedance Spectroscopy as well as surface analysis techniques (Scanning Electron Microscopy and Optical Microscopy) were used for this purpose.

The results obtained in this work indicate that all the employed LSM treatments are able to refine and homogenize the microstructure of the alloy, which improves the corrosion resistance of the as received material. The correlation between the microstructure changes and corrosion resistance will be discussed in the final report.

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The effect of different heat treatment on the wear and corrosion behavior of a Bronze Al-Ni alloy

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Abstract

Bronze alloyed with aluminium, about 10% (w/w%), represents an optimal compromise between mechanical properties and corrosion resistance. Also, small quantities of Fe and Ni may be added to aluminium bronzes to modify their mechanical properties and corrosion resistance[1-3]. These alloys are metallurgical complex materials in which small variations in composition can result in the development of markedly different microstructures, with the corresponding variation in properties.

Generally those alloys are employed in as-cast condition, but in the literature there are recommendations to improve their properties by submitting them to different treatments. It is known that some thermal treatments improve mechanical properties but turn worse the corrosion resistance. Therefore, a trade-off between mechanical properties and corrosion resistance should be considered in the treatment design.

In this work, two different treatments (annealing, and deep cryogenic treatment (DCT)) were carried out in a complex bronze Al-Ni alloy. The treatments were compared in terms of microstructures produced, tribological behaviour and corrosion resistance. The friction and wear behaviour were assessed using a pin on disk tribometer. The influence of the microstructural changes and corrosion behaviour were analyzed by using characterization techniques as Scanning Electron Microscopy (SEM) and Optical Microscopy (OM) combined with potentiodynamic polarization and electrochemical impedance spectroscopy (EIS). Further, dealloying corrosion resistance of those materials was studied.

Experimental results indicate that under normal casting conditions the microstructure of the alloy consists of light etched areas of α-phase, several intermetallic phases referred as κ-phase and some retained β-phase (Al rich). No differences were detected due to DCT. The annealing treatment results in elimination of the retained β-phase and increment of the density of the fine κ-phase precipitates in the α-phase, which represents an homogenisation of the microstructure.

The analysis of the friction and wear behaviour showed that the relative fraction of the different phases plays a significant role in the tribological properties.

The polarization curves and EIS data indicated that annealing and DCT treatments provide increased resistance to electrochemical corrosion. In dealloying corrosion test, the specimens submitted to DCT showed better performance compared to the other materials.

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Influence of two ASTM surface finishings in the corrosion behaviour of stainless steels AISI 304 and AISI 436

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Abstract

The use of stainless steels in replacement and repair of damaged structures is becoming a normal practice in many civil constructions in marine and industrial environments, where the more resistant steel is placed in contact with the aggressive medium. Among stainless steels, austenitic stainless steels are the most frequently employed due to their good corrosion behaviuor and optimal mechanical properties. The demand in this area has grown exponentially in the last few years. However, stainless steels have an important drawback, the relatively high cost due to the Ni content. Ni is one of the alloying elements that increases significantly the cost of austenitic stainless steels, above that of other alloying elements such as Mo.

The use of ferritic stainless steels with high Mo content is becoming a good alternative as replacement of austenitic stainless steels, due to their excellent resistance to corrosion combined with good mechanical performance, at a relatively low cost [1].The presence of Mo is widely recognized for its beneficial effect on the corrosion resistance of stainless steels and has been studied extensively in the literature[2].

In this work the corrosion and tribological behaviuor of a ferritic stainless steel with high Mo content (AISI 436) is compared with a highly employed austenitic stainless steel (AISI 304). Moreover, the influence of the surface condition on the corrosion resistance is analyzed using three different surface finishing degrees: commercial finishing 2B and BA and polished down to 1 μm. The surface condition is a key parameter related to the onset of pitting corrosion in presence of chlorides.

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An investigation on the electrochemical behaviour of a Friction Stir Processed Mg-Al-Mn Alloy

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Keywords: FSP, Magnesium alloys, EIS, Corrosion

Abstract

The interest in magnesium alloys in the automotive industry has considerably increased in recent decades to achieve a reduction in the vehicle weigh, mainly due to their high specific strength and light mass, enabling greater efficiency in fuel consumption. But the low conformability of Mg alloys has limited their applicability in the sector. The Friction Stir Processing (FSP) technique allows obtaining, in cast and wrought magnesium alloys, homogeneous and ultra fine grain (UFG) structures in the stirred zone, achieving super-plastic behavior and good low-temperature ductility at high strain rates [1]. However, since magnesium is a very reactive metal, the corrosion resistance of its alloys becomes a key point.

In the present work, an AM60 magnesium alloy has been processed by FSP using a cooper backing plate and a cooling agent (N_2 liquid) to obtain a sub-micron grain size in the stirred zone (average size from 120 nm to 550 nm at the bottom part of the stirred zone and from 400 nm to 1100 nm at the top, according to the temperature variation during the process [2]). Electrochemical tests were made on the surface and cross section of the procesed zone, registering the open circuit potential and the electrochemical impedance over a 7 hours period. The results are compared to those of the base metal. Tests were carried out in 1 M NaCl solution at 25ºC. After the electrochemical measurements, samples were analyzed by optical microscopy (OM) and scanning electron microscopy (SEM).

The results of electrochemical impedance spectroscopy show that the value of the impedance of the alloy increases with time in all the considered zones of the samples. In the surface of the stirred zone, the impedance is higher than in the base material. Tests performed on the cross section also show an increase in the value of impedance with time, and these values are significantly higher than in the base material and the surface of the stirred zone.

Samples were examined by SEM and the influence of the second phases precipitates (β-$Mg_{17}Al_{12}$, Mg_2Al and AlMn) and the heterogeneous distribution of Al in the matrix is considered at beginning of the corrosion process of the magnesium alloy. In the nugget, as a result of the severe plastic deformation and dynamic recrystallization produced by the friction, the precipitates are mostly dissolved so the degree of homogenization is greater and therefore the impedance of this area is greater than in the surface.

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A Vision-based IEKF Full-Motion Estimation on Long-Deck Suspension Bridges

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Abstract

Structural Health Monitoring (SHM) is an emergent powerful diagnostic tool which may be used to identify and to prevent possible failures of the various components that comprise an infrastructure. In the particular case of a suspension bridge, the measurement of the deck's motion (displacement and rotation) plays an important role for its safety evaluation, namely at the middle span where the displacements are more significant and may achieve a couple of meters. However, in these cases, the traditional displacements transducers cannot be used because there are several constrains, namely the absence of a fixed point in the neighbor of the part to be monitored and the high amplitude of the displacement.

To overcome the foresaid limitations, we developed a non-contact vision-based measurement system, with dynamic response, accuracy and amplitude range well-suited to the physical phenomenon, allowing estimate the 6-D motion of large structures, and in particular, of long-deck bridges. The system setup comprises a set of digital cameras coupled to large focal lenses, fixed at the pier's base – reference point –, tracking the position of a set of active targets fixed in the deck – monitoring zone. The active targets, built with LEDs, radiate optical power with near infrared wavelength, whilst the cameras provide images at high sampling rate and high resolution. The system aims to measure displacements higher than a couple of meters, with a standard accuracy and resolution better than 10 mm and 1 mm, respectively, with a minimum sampling rate of 20 Hz. To accomplish these goals it is essential: i) performing the vision system calibration; and ii) modeling the motion of the structure.

The current communication subject covers the second issue – motion estimation[1]. The communication describes a kinematic model-based to estimate the motion of a structure from a sequence of images captured by the set of cameras along the time. The images captured by all cameras are combined in an Iterated Extended Kalman Filter (IEKF) together with a trajectory model to estimate, among others parameters, the 6-D structure's motion (displacement and rotation) along the time. The requirements are a minimum of two cameras and a minimum of three non-collinear targets (control points).

Results related to the performance evaluation, obtained by numerical simulations and real experiments, are presented. The scenario conditions created for the numerical simulations were inspired in the suspension bridge 25 de Abril over the river Tagus, in Lisbon, whilst for the real experiments we used a reduced structure model to fix the targets and to impose the controlled motion (translation only). The simulation results showed that, even in an environment severely affected by disturbance, it is possible to measure the vertical and the transversal displacements with a standard accuracy far lower than 10 mm and also a substantial decrease of the deviation in displacement and rotation when the motion estimation is performed with an IEKF versus the traditional method. Related with the real experiments, performed in indoor and outdoor environment, the results showed a high agreement with those obtained by numerical simulation.

Fatigue crack propagation behaviour of a puddle iron under constant and variable amplitude loading

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Abstract

The main goal of this paper is to assess the fatigue crack propagation behaviour of a material from an old riveted steel bridge (see Figure 1), based on an experimental program of constant and variable amplitude fatigue tests. The material under consideration is a centenary puddle iron, which information on fatigue crack propagation, under variable amplitude loads, is not available in literature.

An experimental program was performed to characterize the fatigue crack propagation behaviour of the material, using Compact Tension (CT) specimens under the following loading conditions: constant amplitude, constant amplitude with single overloads and variable amplitude block loading. The derived constant amplitude data is compared with data available in literature for other bridge material (see Figure 2). Furthermore, a crack closure analysis was performed using electrical strain gauges applied on the back face of CT specimens.

Finally, in this paper the results were compared with several models. The Paris model, with the linear damage rule by Miner was used. More complex crack propagation models, able to model retardation effects of single overloads was considered, as the Wheeler, the modified Wheeler, the Hudson and the modified Miner models, were included in the assessment.

Figure 1 - *Fão riveted road bridge*

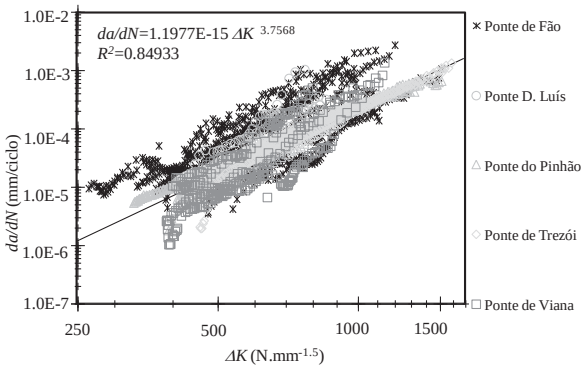

Figure 2 - *Comparison between fatigue crack growth data of several materials from metallic bridges*

A contribution to the characterization of the mechanical behavior of S355NL structural steel

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Abstract The present work is a contribution to the characterization of the mechanical behavior of a commonly used structural steel, S355NL, through fatigue crack growth rate and toughness measurements performed on 32mm thick C(T) specimens.

Further to a full characterization of the Paris law regime, the near threshold stress intensity factor range was experimentally measured for the load ratios R = 0.1 and R = 0.7, and crack closure measurements were made in order to explain the different values found for both load ratios. Flat surface and side grooved C(T) specimens were used for fracture toughness determination. Substantial stable ductile crack growth was observed, particularly in the non-grooved specimen as expected. The maximum load J_0 value was taken as elasto-plastic toughness measurement, and a very substantial drop in fracture toughness was observed for the grooved specimens. In order to explain the fracture toughness differences between flat surface and grooved specimens, a 3D finite element analysis of both types of specimens was performed using the software ABAQUS and the modified virtual crack closure technique (mVCCT). The finite element analyses indicate a strong increase in degree of plane strain for the grooved specimens.

Figure – a flat surface C(T) specimen after toughness testing, exhibiting ductile rupture.

Acknowledgments
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Novel Retrofitting Solutions for Masonry Infill Walls Based on Braided Fibrous Materials

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Abstract

The vulnerability of unreinforced masonry walls (URM) under seismic events, and particularly masonry infill walls, causing huge damage to human lives, has revealed the need for efficient retrofitting solutions. In this context, the present paper reports the development of a new reinforcing material for masonry walls based on braided fibrous structures. These fibrous materials were developed through braiding of polyester yarns around a core made of either glass or carbon fiber (core reinforced braid) or without any core (simple braid). Traditional masonry walls specimens, built with horizontally perforated clay bricks and general purpose mortar, were retrofitted with the braided materials by embedding them into the mortar plaster in a mesh like configuration. The flexural behavior of the reinforced masonry walls was compared with URM and walls retrofitted with more commonly used glass fiber laminates using the same configuration and process. From the experimental results presented in Figure 1, it is evident that, although the highest flexural strength was achieved in case of masonry reinforced with glass laminates, it showed much lower ductile behavior than those reinforced by braided structures with glass or carbon core. Among the various braided structures, the one with carbon core was found better in terms of both strength and deformation. This indicates the capability of this type of braided materials for sustaining the masonry wall structure after occurrence of a seismic event and thereby reducing the damage by avoiding the complete collapse of the walls.

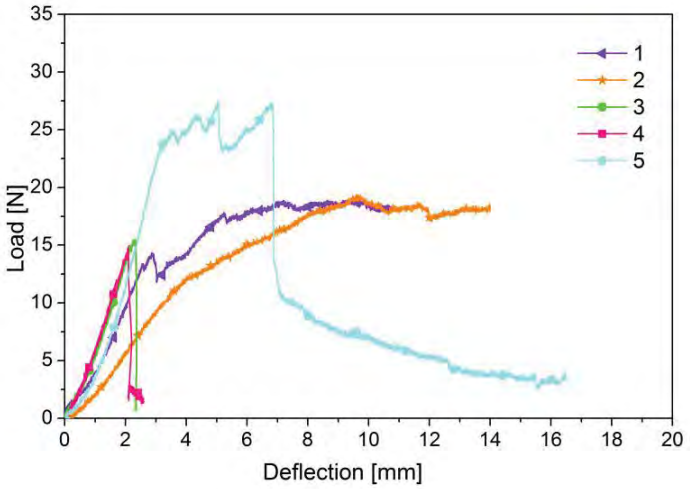

Figure 1 - *Load-deflection diagrams of masonry walls: (1) reinforced by braided structure with carbon core, (2) reinforced by braided structure with glass core, (3) reinforced by simple braided structure, (4) unreinforced and (5) reinforced by glass laminate.*

Locating and Quantifying Damages in A 3-D Frame Using Residual Error Method

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Abstract

Despite the significant advance of new technologies applied in the field of civil engineering, the structures continue subjected to the occurrence of faults which are produced, many times, in normal conditions of use. The detection of these faults or damages present in a structure may be done by the analysis of some dynamic characteristics, as frequencies and mode shapes. In this work, the Residual Error Method (Genovese, 2000, Brasiliano et al., 2004) was extended in order to be applied in 3-D frames. This method is based on the alteration, produced by damage, in the dynamic properties of structures and the location is done by observing the error present in the modal equation. The damage quantification consists in looking for the minimum error in the modal equation by an iterative process. Results obtained by this method allow to locate and quantify damages introduced in structures. A numerical model of a 3-D frame was idealized and some damages were introduced in its elements in order to verify the method performance. Damages are introduced in the finite elements of the model by an inertia reduction. From the obtained results the Residual Error Method was very efficient in the damage identification of the considered structure allowing to locate and quantify the damages successfully.

Development of Braided Composite Rods for Structural Health Monitoring

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Abstract

Self-monitoring of deformation and damage is an essential need for modern structures in order to avoid accidents from sudden collapse. Fibre reinforced composites, as reinforcing materials, have opened up the possibility of designing self-monitoring structures without the need of external sensing elements. The self-sensing composites contain a conductive component usually carbon fibres which change their electrical resistance upon deformation. Hybrid composites composed of a mixture of carbon and glass fibres proved very effective in generating alarm signal by sensing damage well before the structure collapse. However, the existing hybrid composites show very less sensing capability at low strain level, which makes them unsuitable for continuous health monitoring of structures.

In the present research, we have investigated the possibility of using core reinforced braided composite rods (BCRs) for continuous monitoring of very low deformation as well as damage. The BCRs were produced by braiding polyester fibres around a resin (unsaturated polyester) impregnated core composed of glass and carbon fibre mixture using a simple, single-step and low cost braiding process, patented by authors. The sensing behaviour was characterized by monitoring the change in electrical resistance with deformation using two terminal dc method. Monotonic tensile testing up to fracture was used to measure damage sensing capability, whereas the continuous monitoring behaviour was evaluated using cyclic tensile tests at very low strain level. The effect of core composition (weight ratio of carbon and glass fibre) and various braiding process parameters such as take up speed, braiding, angle and pre-tensioning on the sensing capability was thoroughly investigated.

The experimental results showed that the composition with less amount of carbon fibre in the core is advantageous in terms of both damage sensing and continuous monitoring. The various braiding process parameters were found to have strong effect on the arrangement of core carbon fibres, which in turn controls the sensing behaviour of BCRs. The braided rods having optimum composition and produced using optimum parameters showed reliable damage sensing as well as gauge factors much higher than the existing hybrid composites in case of continuous strain sensing. Based on the experimental observations, the probable mechanisms for damage and strain sensing have also been proposed.

Study of Sandwich Panels with Metal Foam Core for Forming Process

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Abstract

On this work, the authors present the development and evaluation of an innovative system able to perform reliable panels of sandwich sheets with metallic foam cores in order to assist in the design process of forming of composite blanks. This suitable combination of materials provides, on one side, a higher level of strength and stiffness ratios to its mass or weight. As a result of these specific properties this kind of composite turns out to be a highly attractive material, particularly for "ultra-light" structural applications. The present work aims to study the behavior of sandwich structures, composed by a foam core with two outer layers of metal sheet (all structure being aluminum). The study of the composite structure behavior, its mechanical characterization and numerical modeling is essential to analyze the mechanical performance of structures based on this type of materials. This step is fundamental in preliminary design, since the different materials of the composite structure show different mechanical responses. The differences in mechanical behavior are demonstrated by the axisymmetric compressive stress states tests and also by the influence of hydrostatic pressure in the yield of the aluminum foam porous material, while the yield of the homogeneous solid material (aluminum sheet) can be considered as pressure insensitive. In order to correctly characterize separately these two materials of the composite (outer layers and core), a set of tests were performed. The characterization of the aluminum sheet was performed in a series of tensile tests, using three different rolling directions. For the metal foam core characterization a series of uniaxial compression tests were performed. The experimentally obtained results were applied in the development of numerical models for this kind of sandwich structure. The models include elasto-plastic constitutive relation, where a distinct plastic domain for different materials is accounted for, as well as, the influence of hydrostatic pressure in the yield of the porous material. Also, the validation of the elasto-plastic models is performed by comparing results obtained by numerical simulation with those obtained experimentally.

Assessment of the interlaminar fracture toughness on nano-filled epoxy/glass fibre composites

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Abstract

Laminated fiber reinforced polymer–matrix composite materials have been used successfully in many industries like aerospace, automobile, marine, military, etc., despite their low interlaminar shear strength, in consequence that conventional manufacturing techniques do not produce reinforcing fibers orientated in the thickness direction to support transverse load. One way recently explored to improve interlaminar shear strength is the use of nanoparticles preferentially orientated in the thickness direction.

Present paper uses a small quantity of nanoclays and carbon nanotubes to enhance the glass/epoxy composites. The paper studied the improvement on the mode I and mode II interlaminar fracture toughness obtained by the use of nanofilled epoxy matrices. The nanofillers used in this work were: walled carbon nanotubes and nanoclays dispersed preferentially orientated in the laminate produced by a moulding in vacuum process. The mode I strength will be determined with double cantilever beam (DCB) specimens, while the mode II damage will be studied with end-notched flexure (ENF) tests. The particles orientation was obtained by TEM observations. The experimental results obtained from the tests with the different setup material were compared in order to analyse the benefit effects obtained by the nanofiller addition and it relationship with particle orientation.

Mechanical behavior of composite materials with enhanced energy absorption properties

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Abstract

Composites are natural candidate materials for structural applications requiring optimized strength-to-weight ratios, such as airframes and other types of structures of high performance vehicles. Regardless their obvious advantages, composite materials, and in particular high strength laminates (such as CFRPs), present some downsides that restrain their usage when the design requirements of certain components is mainly driven by the need of high energy absorption capabilities. This can happen, for example, when impact loading is expected or if the dynamic response of the component is required to have improved damping characteristics.

The aim of this paper is to explore the benefits of using cork based composites as a viable alternative towards the improvement of the resilient and energy absorption properties of carbon-epoxy laminates. Two types of materials configurations were considered: 1) a cork based core in a sandwich component; 2) a conventional CFRP laminate with embedded cork granulates. Static properties were obtained from 3-point flexural testing whereas the dynamic behavior was characterized through low velocity impact and fatigue testing. Experimental results were supported by an analysis of the damage extension based either on microscopic observations or residual strength testing.

Regardless the types of materials configuration, results are encouraging about the positive effect of viscoelastic materials in the improvement of the energy absorption properties of high performance composites with a minor impact in their original mechanical properties, which is a major benefit for the structural integrity of aerospace structures under severe operational conditions, such as foreign object damages and aeroelastic problems.

Effect of composite patch in repaired plate on FCG under different tempered situation

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Abstract In this paper an investigation on the effect of composite material patch repairing were conducted to characterize the fatigue crack growth behavior in 6061-T6 and 6060-T651 Aluminum alloys (3 mm) plate with a single sided fiber reinforced composite patch. Using empirical analysis, the stress intensity factors were calculated when critical stress intensity factor are based on patched structure, from which the fatigue crack growth rates were evaluated using Nasgro model based on experimentally data. For the patched and un-patched plate, effect of different stress ratio on fatigue crack growth was investigated. The results show that fatigue life was affected by tempered materials and stress ratio and retardation of crack growth is found in the bonded repair. Effect in increasing of stress ratio is characterised by an increasing in fatigue life and fatigue crack growth rates (FCGRs) when maximum cyclic loading is maintained constant.

Keywords: fatigue crack, repair composite patch, retardation, Al-Alloy

Damage tolerance verification of composite spacecraft structures

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Abstract

This works describes the analysis models required for the certification procedure of composite spacecraft structures. The main failure mechanism addressed is delamination and three levels of analysis with increased complexity and accuracy are proposed (Figure 1). Level 1 corresponds to the crack tip element and it enables fast predictions of delamination propagation that are suitable for preliminary design. Level 2 corresponds to the use of the virtual crack closure technique to predict the onset and the stability of delamination propagation. Finally, level 3 corresponds to the use of cohesive finite elements implemented in non-linear finite element codes. The range of applicability of each analysis methods and the associated best practice guidelines will be presented.

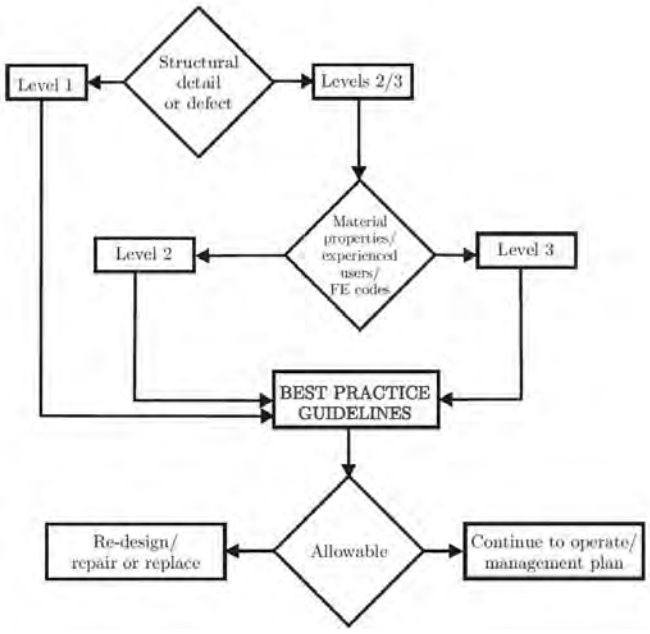

Figure 1 - *Proposed method for the selection of the level of analysis.*

Buckling Response of Hygro-Thermally Curvature-Stable Laminate with Extension-Twisting Coupling

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Abstract The bounds on buckling strength of simply supported laminated plates with extension-twisting coupling are investigated. A closed form buckling solution is shown to be applicable to this class of coupled laminate, for which stacking sequences can be manufactured using standard ply-angle orientations (±45, 0 and 90°), and constant ply thickness. These results are also validated using a commercial finite element code.

Attention is focused on a special sub-class of extension-twisting coupled laminate that is free from thermal distortion[1,2], which generally arises as a result of the high temperature curing process; such special laminates are generally referred to as hygro-thermally curvature-stable. In addition, these special laminates with standard ply-angle orientations have also been shown, experimentally[3], to offer comparable mechanical twist coupling to those with highly optimized free-form configurations.

This particular class of coupled laminate has been used extensively for application to tilt-rotor blade design, where extension-twisting coupling at the structural or blade level is used to develop optimized twist distribution along the blade for both hover and forward flight: a change in rotor speed, and the resulting centrifugal forces, provides the required twist differential between the two flight regimes. This behaviour can also be achieved using laminate level extension-shearing coupling, through off-axis alignment of a balanced and symmetric laminate. However, the compression buckling strength of such blades, which represents an important static design constraint, appears to have received very limited attention.

Closed form buckling solutions are therefore presented for all hygro-thermally curvature-stable laminates with extension-twisting coupling; these consist of 8, 12, 16 and 20 ply laminates within the range of thin laminates investigated, i.e. up to 21 plies. Improvements in the buckling strength have been observed for laminates with standard ply orientations, compared to those optimized for twist using free-form ply orientations. Indeed, initial results suggest that laminates designed for maximum extension-twisting performance correspond to lower-bound buckling strength performance across the entire range of plate aspect ratios.

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Mixed mode behavior for composite bonded joints using the SLB test

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Abstract

The application of composites in industry is increasing due to their excellent characteristics concerning strength and stiffness to weight ratio. These materials demand composite bonded joints to take advantage of their full potential as a structural element. In this context, a complete knowledge of the fatigue behaviour of composite bonded joints is fundamental. Adhesive joints are often loaded under mixed mode conditions. In this work, the Single Leg Bending test was used to characterize the fatigue/fracture behaviour of bonded joints. This test provides a fixed mixed-mode ratio ϕ=40º (Figure 1) which was used to determine the parameters (C_1 and m) of the Paris-law. These values were plotted in conjunction with the ones of the pure modes in order to establish their evolution as a function of mode-mixity (Figure 1).

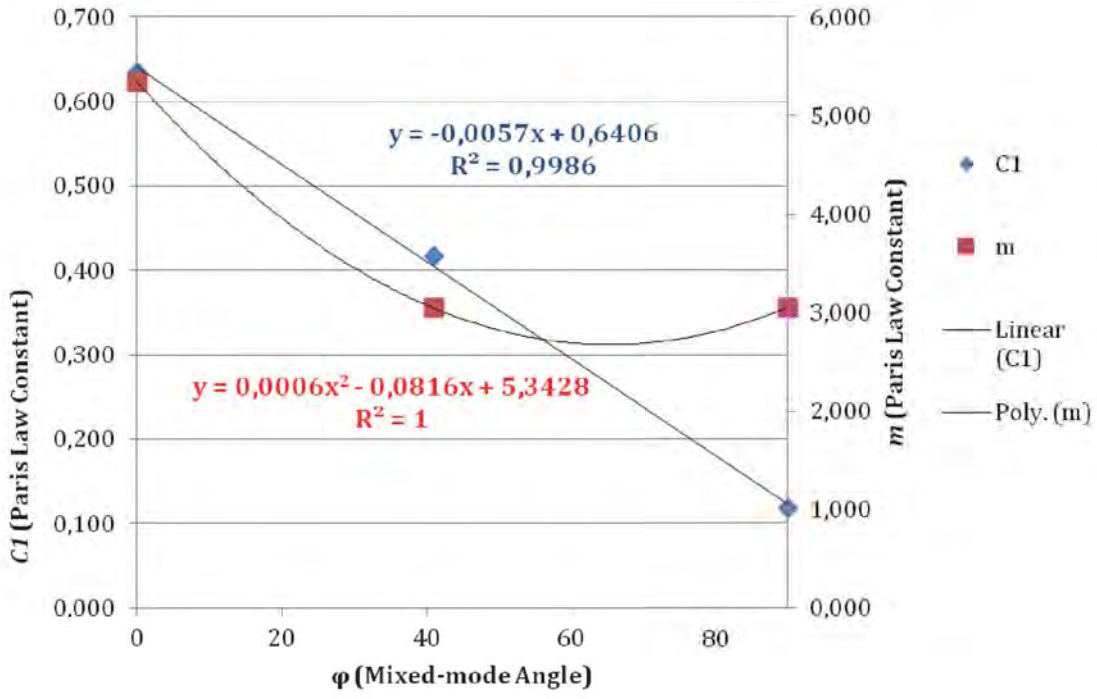

Figure 1 – *Paris-law Constants as a function of the mode-mixity.*

Experimental Investigation of Initial Flaws in Aircraft 2024-T3 Thin Sheet

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Abstract

The aircraft fuselage of a basic-to-advanced trainer is a semi-monocoque structure, with thin skin, conventional bulkheads and stringers. Most of those components are made of aluminium alloy 2024-T3 thin sheet. Maintaining such aircraft structural integrity to ensure safe operation of the fleet is critically dependent on accurate modeling and reliable prediction of fatigue crack growth in such a thin-walled airframe subjected to flight spectrum loading. One of the challenging topics in the prediction of fatigue crack growth is to identify representative initial flaws and defects that can cause fatigue crack initiation and subsequent crack growth in aircraft structures. This paper, therefore, addresses this challenge with a critical literature review and experimental assessment of initial flaw types that may cause fatigue crack initiation and subsequent growth. With a focus on aluminium alloy 2024-T3 thin sheet for a specific trainer aircraft, the results covers various discontinuities from microstructural constituent particles inherent from the material process to macrostructural defects and surface discontinuities (such as burrs and machining marks) introduced during the production of airframes. Considering that not all discontinuities in aluminium alloy 2024-T3 thin sheet will be definite sources of fatigue crack initiation, the material flaws and machining defects that dominantly control fatigue cracking are investigated experimentally. The paper concludes with a summary of fatigue initiation dominated flaws and defects, and based on the findings, some recommendations were made for fatigue crack growth prediction for the thin-walled aluminium alloy 2024-T3 airframes.

Finite element crack propagation analysis of shear loaded buckling panels

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Abstract

Test results of crack propagation in aluminum panels due to cyclic shear loading show that the maximum principle stress is the main factor influencing the crack growth rate. For larger cracks it is accelerated by the increasing out-of-plane deformation. To analyze these influences, a finite element model is presented, which respects the boundary conditions of the test-set-up. Results of the stress intensity factors K_I calculated by the FE model provide a function which is used to run a crack propagation analysis based on Forman law. The results are in good agreement with test results and improve the prediction of a simplified approach.

Limitations of the application are discussed.

Investigation of Fatigue Scatter in Laser Peened Aluminum Test Coupons

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Abstract

The military aircraft that comprise the current fleet of the United States Air Force (USAF) have been flying, on average, for more than 20 years [1]. As these planes continue to age, service life extension and maintenance reduction can become costly concerns. Recently, the Air Force Research Laboratory (AFRL) has been investigating the application and transition of laser peening (LP) as a surface treatment for enhancing the fatigue life of airframe structural components. With the LP process, compressive residual stresses are induced mechanically into select near surface regions, the intent being to counter the fatigue-inducing tensile stresses resulting from service loads.

While the focus of this research program has been on the development and validation of physics-based, predictive modeling tools for evaluating the induced residual stresses and subsequent fatigue response, recent laboratory testing in Al2024 fatigue coupons has suggested that, in some cases, the fatigue scatter after LP is applied can be significantly greater than that in the un-peened specimens [2]. From an aircraft reliability perspective, this increased scatter can offset the beneficial effects of LP, and can even negate the potential benefits completely. In these cases, although increases in average coupon life (cycles to failure under constant amplitude, uniaxial fatigue loading) were observed, the range of individual test responses after peening was 2-20 times the range of the un-peened specimen responses.

In this paper, we investigate scatter effects in laser peened Al2024 test coupons using finite element (FE) based sensitivity analysis techniques. Two- and three-dimensional parametric FE models are used in a multi-tier design of experiments (DOE) evaluation, with a simple stress-life algorithm used to estimate the cycles to failure under constant amplitude cyclic loading. Scatter effects are investigated by creating small variations in the LP parameters and assessing their relative contributions within the prescribed DOE framework with respect to the predicted fatigue response. Variations in coupon parameters and applied loading are also studied to evaluate the degree to which small geometric disparities and deviations in service use are affected by the LP application.

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AA2024-T3 FSW tailor welded blanks: fatigue crack growth behavior

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Abstract A 'tailor welded blank' is a part made up of different strengths or thicknesses of an alloy, typically manufactured by laser welding. Although frequent in automotive engineering applications of high strength steel, other applications are of interest, including aeronautical applications with aluminum alloys and using FSW instead of laser. This paper presents a study of fatigue crack growth behaviour of friction stir welded butt joints of plates of different thickness of AA2024-T3, an alloy commonly used in fuselage structures.

Friction stir welding (FSW) is a solid-state joining process which emerged as an alternative technology to join high strength alloys that were difficult to weld with conventional techniques, *e.g.* [1]. An advantage of this joining technique is its low heat input when compared with arc welding processes, allowing the achievement of high mechanical properties, low distortion and low residual stresses. Also, hydrogen cracking or heat affected zone (HAZ) softening phenomena are limited. Crack growth studies are usually carried out using uniform thickness joints, ASTM E647. Nevertheless, for applications such as tailor welded blanks, there is a need to test specimens with defects growing in the thickness transition region. Fatigue crack growth tests on such welded connections are not standard. The present study concerns butt joints made using two AA2024-T3 plates 3.8mm and 4.0mm thick.

The mechanical behaviour of the joint was studied performing tensile and fatigue crack growth tests. The fatigue crack growth rate of cracks growing in different zones of the welded joint (nugget, HAZ) and in base material was analyzed. The influence of the welding process in each weld zone was evaluated using microhardness profiles. Further to higher static properties, welded joints present lower crack growth rates when compared with its base material.

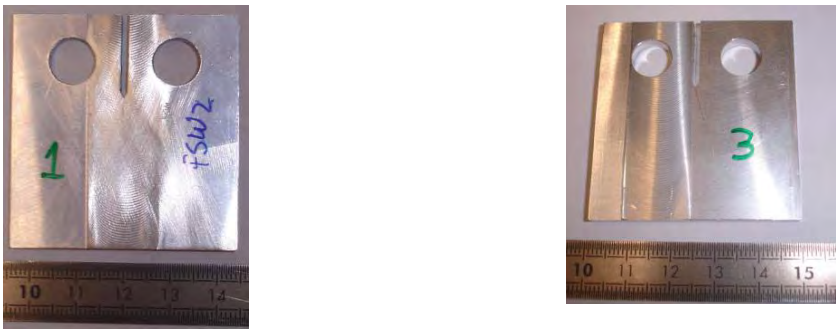

Figure – example of specimens tested, with crack in the nugget (left) and in the HAZ (right)

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Evaluation of multiaxial fatigue loading paths in different shear stress spaces

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Abstract For many multiaxial fatigue models proposed in the literature, the shear stress amplitude is one of the important parameters in their formulations. Conventionally, the shear stress amplitude is usually evaluated by the Longest Projection (LP) or the Minimum Circunscribed Circle (MCC) approach in the shear stress space based on the von Mises equivalence ($\tau=\sigma/\sqrt{3}$) or the Tresca equivalence ($\tau=\sigma/2$) for the multiaxial loading conditions. However, the relationship of the equivalent shear stress related to the axial stress component may vary significantly depending on the type of the material. For example, the ratio of the torsion fatigue limit over the bending fatigue limit $\tau\text{-}1/\sigma\text{-}1$ varies from 0.5 for mild metals to 1 for brittle metals.

Systematic fatigue experiments are presented for a structural steel, 42CrMo4, under typical axial-torsional multiaxial loading paths. A rectangle and an ellipse loading path are used to simulate the same equivalent shear stress amplitude according to the Minimum Circumscribed Ellipse (MCE) approach. A series of fatigue tests for the above two loading paths were carried out in HCF regime, where two non-proportional parameters are used: the phase angle ϕ between stress waves and the stress amplitude proportional factor λ. For the 42CrMo4 steel studied, two kinds of shear stress space for evaluating the shear stress amplitude were used: one is the shear stress space with the equivalence of $\tau=\sigma/\sqrt{3}$ and another is the shear stress space with the equivalence of $\tau=\sigma*\beta$ where $\beta=(\tau\text{-}1/\sigma\text{-}1)$ is determined experimentally from fatigue tests.

The experimental fatigue life results under these loading paths are analyzed and compared with estimations. From this research, it is concluded that the appropriate shear stress space should be used for evaluating the shear stress amplitude concerning the different material behavior for any multiaxial loading path. The MCE approach can treat with the complex multiaxial loading paths in a simple and efficient way, compared to the other approaches.

Fatigue modelling of aluminium plates reinforced with bonded fibre metal laminates

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Abstract

This paper presents the implementation of a finite element model used to establish crack and delamination development in a Glare reinforced aluminium plate under fatigue loading. This model predicts the behaviour of bonded GLARE straps used as crack retarders for life extension of aircraft structures. In particular it takes into account the interaction that exists between the substrate crack and the delamination crack at the interface with the reinforcement.

When subjected to fatigue loading, an aluminium plate bonded with GLARE is affected by several load inputs and crack development processes. The load inputs include thermal residual stresses arising from the elevated temperature bonding of the reinforcement and secondary bending due to the single sided reinforcement configuration. Crack development processes consist of fatigue crack growth in the substrate and fatigue delamination at the interface between the substrate and the GLARE reinforcement. To predict the morphology and the rates of crack growth, a finite element model of the bonded hybrid together with substrate crack and delamination crack growth subroutines has been implemented. The model output relates fatigue crack growth in the aluminium substrate to the fatigue delamination law at the interface and vice versa as this is a non-linear iterative interaction. Based on the stress intensity factor range in the substrate, the subroutine calculates the number of cycles necessary for a certain crack increment of the substrate crack. Then, it uses that number of cycles to determine the increment of delamination at the interface based on the strain energy release rate range at the delamination front. These steps are repeated until the crack length reaches at critical value. The results of the computation are compared with experimental results in terms of both crack morphology and life in fatigue of the hybrid structure.

This research aims at developing modelling techniques that could be used when studying larger reinforced structures found in aircraft.

A discussion on fracture mechanics crack growth-based fatigue life prediction applied to a notched detail

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Abstract

Several methods for fatigue life prediction of structural components have been proposed in literature. The Fracture Mechanics crack growth-based fatigue prediction has been proposed to assess the residual fatigue life of components, which requires the definition of an initial flaw. Alternatively, Fracture Mechanics crack growth-based fatigue predictions may be used to simulate the whole fatigue life of structural components assuming that there are always initial defects on materials, acting as equivalent initial cracks. This latter approach is applied to a notched plate made of P355NL1 steel. Fatigue crack growth data of the material is evaluated using CT specimens, covering several stress R-ratios. Also, S-N fatigue data is available for the double notched plate, covering stress R-ratios equal to 0, 0.15 and 0.3. An estimate of the equivalent initial flaw size is proposed, using a back-extrapolation calculation. The crack propagation model takes into account stress ratio effects, account for propagation threshold and a correction for plasticity. Stress intensity factors are computed using the J-integral technique. The performances of predictions are analyzed and deviations discussed.

Use of Laser Peening for Fatigue Life Extension of Pre-fatigued Components

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Abstract

Military aircraft worldwide are currently being pushed further into, and past, their initial design fatigue lives, the result being continually growing fleets of aging aircraft. This trend has lead to the research and development of surface residual stressing technologies as fatigue life mitigation tools. One such technology, Laser Peening (LP), can induce high-magnitude compressive residual stresses deep into the surface of metallic components. Extensive testing has been conducted to demonstrate the fatigue life extension garnered by LP for a variety of specimen shapes, loadings, and materials. However, the entirety of this testing has been conducted on coupons manufactured from fresh material which has not yet accumulated cyclic fatigue damage.

In this paper, we study the application of LP for specimens that have expended a significant portion of their average fatigue life. The goal is to investigate both the overall fatigue response as a function of pre-fatigue percentage and the interaction with pre-existing damage such as dislocation concentrations and fatigue cracks. Al 2024 specimens were designed and fatigue cycled under three-point bending in a self-aligning fixture. Geometric variations and surface roughness were minimized using careful machining and polishing tolerances (±0.005 and 10 μ-in., respectively). Three levels of pre-fatigue were used: 0, 25, and 50% of the mean total fatigue life of the specimen, as determined by cycling un-peened specimens to failure. After fatigue cycling to the desired amount of pre-fatigue, the specimens were laser peened in the fatigue critical zone using a basic overlapping raster pattern with two layers. The specimens were then replaced into the fatigue frame and cycled until failure.

The failure data was analyzed using a computer intensive statistical re-sampling technique known as bootstrapping to better understand observed trends regarding fatigue scatter, confidence intervals, and life enhancement. Simulation based fatigue life estimations were conducted to evaluate current fatigue life algorithms and their ability to capture both residual stress and pre-fatigue effects. Using experimental, statistical, and physics-based analytical approaches, the effects of pre-fatigue on the effectiveness of LP as a fatigue life mitigation tool will be ascertained.

Structural performance of a lifeboat craft under the application of static and dynamic loadings

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Abstract

The main purpose of this paper is to present the structural response of a lifeboat craft when subjected to the effect of slamming on its bow, but also when submitted to a hypothetical flooding of watertight compartments located in between bulkheads no. 17 and 20 and in the engine and water jet's compartments, separately. Also, special attention was given to the stern of the craft when submitted to jet thrust loads. The studies were accomplished musing the Finite Element Method (FEM) applied to the vessel model. Non-linear FE analyses were performed, which allowed for considering large deformations, hardening and plasticity, through the use of two mechanical behaviour material models. The modes and frequencies of vibration were determined to check for structural resonance problems due to slamming induced loads, considering the sea conditions where the craft operates. The forced frequency response of a specific region on the bow was also determined when subjected to slamming loads applied in a frequency range from 25 to 80 Hz.

The results revealed that the maximum stress induced in the structure due to typical inservice load condition was, in average, of the order of 50% of the yield strength of the materials used in the production of the high speed lifeboat, the aluminium alloys 5083-H111 and 6082-T6.

Figure 1 – *Lifeboat under study*

Application of alternative lightweight structures to support an helicopter flight deck

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Abstract

The main purposes of this article consist in analysing the possibility of implementing tubular structural elements in secondary and tertiary ship structures in order to obtain significant weight reduction and simultaneously maintain or increase its structural resistance.

For that purpose, it was verified the possibility of replacing the beams and girders that support the flight deck of a frigate of the Portuguese Navy (Fig.1), simulating the impact load caused by an emergency landing of a "Super Lynx 300" helicopter over the flight deck. Several analyses were performed, varying the load application point, in order to determine the stress distribution induced in the different elements that compose the structure, in both current and alternative models.

The numerical simulations were performed using the Finite Elements Method (FEM) and the current flight deck and its support structure were simulated, as well as alternative support structures. It was admitted that none of the modelled structural elements would suffer permanent deformation driven by the applied load. Comparing the stress distribution throughout the different models, it was possible to obtain several alternative structures, with weight reductions that could go up to 17%, when considering a factor of safety of 1,5.

Figure 1 – *Helicopter landing on the flight deck under study*

Keywords: Ship's substructures, tubular elements, flight deck, finite element method

Estimation of structural damage on Helicopter tail boom in case of harsh landing events

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Abstract

Investigation about structural damage on Helicopter components in case of harsh landing is poorly described in literature. Most of the studies are focused on the performance of skid gears, covering two main topics: the gear integrity after harsh landing and passenger safety. More studies may be found in the case of aircrafts, with similar purposes.

Nevertheless, the overloads due to unusual landing conditions may lead to distributed damages on the whole frame: in particular the tail boom can be severely exposed to the inertial loads caused by an harsh landing. At present those cases require a maintenance event to assess the integrity of the structure. The ability to detect the onset of damage with a proper sensor system may permit to avoid a similar circumstance, developing a condition based maintenance approach thus reducing the idle time of the machine.

With this in mind, the present work focuses on the evaluation, through the use of Finite Element Model and sub-modeling strategies, of the stress due to harsh landing acting into the tail boom of a medium-weight Helicopter, equipped with wheeled landing gear. Different conditions are considered, studying their influence on stresses, and a monitoring strategy is proposed.

Involved variables for thee assessment of the coupled wind induced fatigue behavior of exposed slender structures.

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Abstract

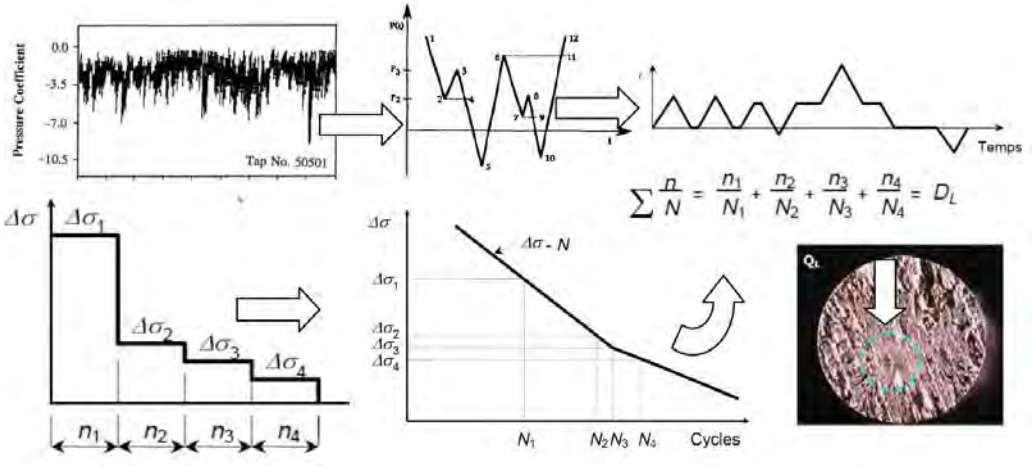
The influence of the wind action in the fatigue of the exposed structures is double since it causes fatigue first by his dynamic action, this is, vibrations produced by wind gusts which cause in time variable stress in the structural elements, and second by his transport action, this is, the corrosion fatigue produced by the chemical elements transported by the wind like the common ones: chlorides, moisture, traffic emissions etc. or a priori the more rare industrial chemicals.

The dynamic action of the wind is studied as a random variable load with many variables involved and is considered as a broad band process, studying it by stochastic means and counting the cycles from the pressure record by the Rainflow method.

The transport action of chemical substances which cause corrosion fatigue depends on the material itself, the possible imperfections, the temperature, the amount of this chemical substance present in the environment, the possible interactions with others like moisture and the presence of stresses in the structural element. Therefore it is necessary to consider the two ways of fatigue, dynamic and corrosive, a coupled system acting in synergy and also consider the assessment of the total damage by the use of any existing rule if fits.

The objective of this paper is to list all the variables involved, their magnitude order and the information availability for their correct characterization.

As a conclusion, in the frequent case that precise information was not available the fuzzy method is suggested to save the lack of crisp bounds and relax the needing for precise values and bounds.



Structural integrity assessment for a component of the bucket-wheel excavator

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Abstract

Different ways to demonstrate the integrity of structures include the test of the structure itself, the test of reduced models, the use of computer models (i.e. Finite Element Models) and the application of assessment procedures. While the first three ways are only applicable to case-specific situations, this is not the case of the assessment procedures. The structural integrity assessment procedures are used not only to show that the components are properly designed but also to demonstrate that they will operate safely during their design life. The correct use of these procedures may have relevant consequences from an economical point of view, avoiding the oversizing of components or unnecessary repairs and inspections. At present, structures are, in general, excessive used both as loading level and the time of operation. When this happens, the stresses acting on their constituent elements vary if the stiffness of some of them changes. One clear example of this situation is the effect produced by the crack propagation. However, the existing assessment procedures only address separately the analysis of uncracked redundant structures in order to define the stresses acting in the different sections and the analysis of the cracked sections considering the previously determined stresses.

This paper presents a methodology for assessing the structural integrity of a tie member from a bucket-wheel excavator, ERC 1300 model, that were in operation for about 20 years. The tie member is made of S355J2N structural steel. Following the period of operation, the occurrence of microcracks which can propagate by fatigue is almost inevitable. It is therefore necessary to analyze the structural integrity and the remaining life of the component analyzed.

In principle, the assessment methodology is based on three steps: 1. The evaluation of mechanical properties of the material component. 2. A FEM analysis using FRANC 3D software package to estimate the evolution of the stress intensity factor based on crack length and applied stress. 3. Risk factor estimation and remaining fatigue life predictions based on FAD diagram and Fatigue Damage Tolerance concept. Due to the weight of sustained arm, the tie is static loaded with a tensile stress of about 73.6 MPa. This imply that during excavation, the tie should not work at variable amplitude loadings with stress ratio lower than 0.2. Following the evaluation procedure were made predictions of failure risk factor and remaining fatigue life function of crack length and variable stress range, for a high level of confidence. As results of this analysis was implemented a program for verification and inspection of the tie member for the loading state and development of small cracks during operation.

This case study demonstrates the advantage of implementing the "fail – safe" design philosophy in the analysis of the behavior of structures under variable loads with highly expressed dynamic - periodic character.

Structural Integrity of Tires

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Abstract

This work is concerned with the damage evolution of the external tread of a standard elastoplastic tire under radial fatigue. A Radial Fatigue Test (RFT) is modeled by a two dimensional non-linear finite element framework, where the tire is considered on steady-state rolling [1]. The cycle of forces is described by the friction trace [2] and the formulation employed to estimate the Wear is the Dissipated Energy Method [3]. The frictional interaction between the contact patch (i.e. the area of the tread that is in contact with the road surface) and the ground is evaluated using a Dual-Mortar formulation [4,5]. The use of a dual-basis for the lagrangian multipliers allows a reliable enforcement of the contact constraints and a precise computation of the loading cycle. Analysis of the effective plastic strain and the accumulated damage are undertaken in order to evaluate the structural integrity and the kinematical degradation of a tire.

Keywords: Radial Fatigue Test, Dissipated Energy, Integrity of tires.

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Turbomachines blades integrity and seal materials interactions - Dynamic experimental analyses.

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Abstract Abradable seals are used in jet engines to minimize clearance between rotor blade tips and casing, and hence optimize the compression efficiency. Blade-seal interferences occur during engine operation, which may lead to severe blade-casing sealing deterioration or blade failure. In order to improve the mechanical design of the engine, the coupling between blade dynamics and seal material wear mechanisms has to be experimentally studied. A dedicated and original test rig has been developed to produce blade-seal interactions which are representative to jet engine compressor stage conditions. The reversed curvature configuration – compared to compressor conditions – allows an accurate instrumentation of the blade-seal interaction area (displacements, force and high-speed images). The analysis of the interaction between a titanium alloy (TA6V) blade and an AlSi-hBN abradable seal shows that blade dynamics correlates well with the macroscopic wear profile of the seal. A time-frequency decomposition is used to go further into dynamic measurement interpretation. This analysis shows the superposition of blade-seal interaction dynamics and test rig eigenmodes, which are known thanks to an experimental modal analysis.

Defects Detection in Aeronautical Structures joined by Friction Stir Welding

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Abstract

Damage tolerant design philosophies have a considerable impact in the weight reduction in aeronautical structures and at the same time in increasing the life cycle extensively without compromising the structural integrity due to the crack nucleation prediction and fatigue crack growth estimations. These phenomena allow the definition of maintenance tasks to check structural defects and their severity. The application of non-destructive techniques (NDTs) has been essential for these maintenance check-ups, since the minimum defect size to be considered in the life cycle estimations of the structure needs to be detectable by the available techniques.

The NDTs are taken into account in early phases of the structural design, given the close interplay of actual defects measurement, the probability of detection and damage propagation modeling for damage tolerant assessments and structural optimizations.

In this work, the application of different state-of-art non-destructive techniques is presented, focused in structures where the riveting process can be replaced by friction stir welding. This joining process presents several advantages over riveting processes, although is require to ensure the structural integrity in the joint. The NDTs considered are based on different physical phenomena, giving indications about the best approach for the detection of the most demanding defect in friction stir welds, root flaws.

It was concluded that techniques based on the eddy currents will have an important role in future NDT for new manufacturing processes as friction stir welding, since these processes have good capabilities to detect near surface defects and good resolution for the small defects detection.

Wheel/rail contact: fatigue behaviour

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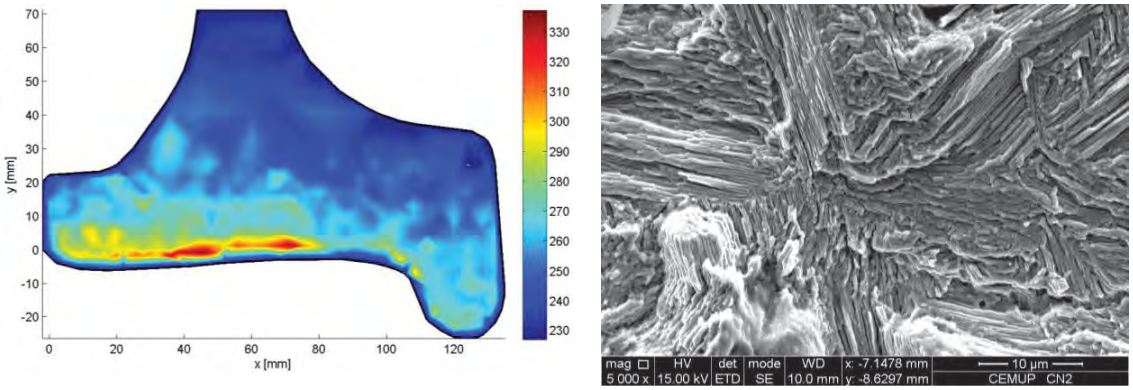
Abstract The work presented is part of a project where it is intended to develop a methodology to anticipate the need for repair or replacement of wheels or rails, and in particular to establish time limits for intervention on wheels or rails where one or more defects were detected.
Fatigue crack growth rate measurements, including low values of stress intensity factor range, and twin disc tribological tests, are being performed in order to characterize the fatigue crack initiation and propagation behavior of wheel and rail materials, as this is essential for the objectives mentioned above.
Further to initiation of defects in the contact region, tribological twin disc tests also provide wear rate characterization. Some related issues as chemical compositions, microstructure analyses, wheel hardness profile and striation spacing counting in the wheel and rail were also assessed and will be discussed in the paper.



(a) (b)

Figure 1 – *On-going characterization work: a) wheel hardness profile [HV30]; b) rail material striation.*

Acknowledgements
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Wheel/rail contact fatigue: theoretical and experimental analysis

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Abstract Railway sector places an important role in the means of transportation for some countries. Safety is, as such, of prime importance. Such components and structures are expected to be in service for long periods of time, therefore a rolling contact fatigue (RCF) analysis on such elements becomes crucial.

The aim of the present work is to study the wheel/rail contact fatigue, i.e., a theoretical and experimental analysis of the mechanical behavior between the wheel and the rail under cyclic loading conditions was performed.

Experimental work was carried out by a biaxial fatigue testing machine, where different loading paths, i.e., typical combined compression stress and shear stress conditions simulating the wheel rail contact were applied. Cyclic elastic-plastic behavior of the materials used in this study was also obtained.

Numerical and theoretical models were implemented. The numerical study enabled us to characterize the nature of stresses that are present in the wheel, regarding the rolling direction. Other approaches were more focused on the material's mechanical behavior and also used to compute the crack initiation plane angle – critical plane models. To characterize fracture surfaces under these typical loading paths some fractographic analyses were also carried out.

The paper concludes with some remarks: the loading trajectories severely affect the fatigue life, the initial crack plane and consequently the fracture surface. It also discusses how this damage phenomena (RCF) is influenced by the stress states of the wheel/rail material.

Cohesive zone modeling of the DCB test in cortical bone tissue

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Abstract

Fracture characterization of bovine cortical bone tissue has been performed in hydrated and dehydrated specimens using the double cantilever beam test (DCB). The aim was to analyze how the presence/absence of water influences the material fracture. Resistance-curves were obtained experimentally using two different methods: the Compliance Based Beam Method (CBBM) and the Modified Experimental Compliance Method (MECM). Both provided consistent results, revealing that toughness in hydrated bone is three times as big as in dehydrated one. Based on experimental data, parameters of the bilinear softening damage law were also determined for hydrated and dehydrated bone using an inverse method based on a developed genetic algorithm. Significant differences were observed on the shape of the cohesive laws as well as on the respective parameters, thus being concluded that water plays a fundamental role on bone fracture behavior.

Keywords: Bone, Fracture characterization, Mode I, Double Cantilever Beam test.

Effects of the Shear Strain Rate on the Torsion of Trabecular Bone

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Abstract

As one of the major functions of bone is to provide structural support for the musculoskeletal system, it is important to evaluate its mechanical strength. Bones may be subjected to multiaxial stresses due to bone pathologies, accidental loads which may lead to hip, wrist fracture or to a prosthetic joint replacement. Torsional loading may lead to fractures, especially involving long bones from lower limbs. The aim of this work was to study the effect of age on the shear properties of trabecular bone, with a particular emphasis to the effect of the strain rate in older female osteoporotic patients (from 68 to 86 years old). Cylindrical samples were core drilled from human femoral heads along the primary trabecular direction. The cylinder's ends were polished and embedded in blocks of polymer material which fit the grips of the testing device. Deformation rates of 0.005, 0.01 and 0.05 rad s^{-1} were applied. From the torque-angular displacement curves, the shear stress-strain curves were obtained. The maximum shear strength, the ultimate strain and the shear modulus (i.e. the slope of the linear region) were determined. The results showed that the strain rate variation did not reflect any relevant differences on the determined parameters, for female patients of three age-groups included.

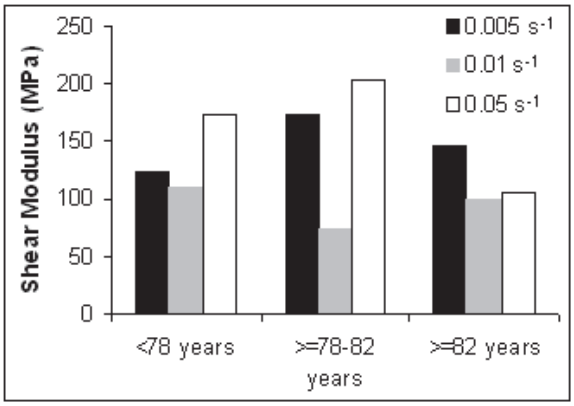

Figure 1 – *Shear modulus for different age-groups and three strain rates, respectively, 0.005, 0.01 and 0.05s^{-1}.*

Fracture characterization of cortical bone tissue under mode II loading using the end loaded split and the end notched flexure tests

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Abstract

In this work, a comparison between the End-Loaded Split (ELS) and the End Notched Flexure (ENF) tests is made concerning their adequacy to evaluate mode II fracture properties of cortical bone tissue [1]. In both tests, two slight longitudinal grooves were machined in each lateral side of the specimen to provide self-similar crack propagation along the longitudinal specimen direction. To overcome the difficulties intrinsic to crack length monitoring during its propagation, equivalent crack methods were adopted as data reduction schemes. These methods do not need crack length measurement during the course of the tests, and provide the assessment of the equivalent crack extent as a function of the current specimen compliance using the beam theory. Both tests provided consistent results. This work showed that the ENF test presents some advantages when compared to the ELS in which concerns the identification of mode II fracture properties in bone.

Keywords: Bone, Fracture characterization, Mode II, End-Loaded Split test, End Notched Flexure test

Compressive Fatigue Tests on Trabecular Bone

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Abstract

An understanding of the mechanical behavior of bone is extremely important, as it provides structural support for the musculoskeletal system. Bone is loaded in fatigue as a result of prolonged exercise and repetitive activities, which may lead to a reduction in stiffness and a consequent increase of the risk of fracture. Nevertheless, there are few studies on the fatigue behavior with human specimens. Patients with hip osteoarthritis are prone to bone failure, being frequently submitted to total hip replacement surgery. In this work, trabecular bone cylinders extracted from human femoral heads were loaded under compressive fatigue. Samples were preconditioned for ten compression cycles under strain control. The initial secant elastic modulus, E0, was determined from the slope of the 10th cycle. The initial modulus was used to normalize the interval of applied stress, which was $\Delta\sigma/E0=0.006$. The fatigue test was performed at a frequency of 2Hz (physiological frequency) and tests were stopped after reaching a strain of 0.8% or 200,000 cycles. Figure 1 exhibits a stress-strain plot for a sixty-seven-year-old male patient. The fatigue behavior of trabecular bone is characterized by an increase on the residual strain, a broadening of the hysteresis loops, and by a decrease of the secant modulus.

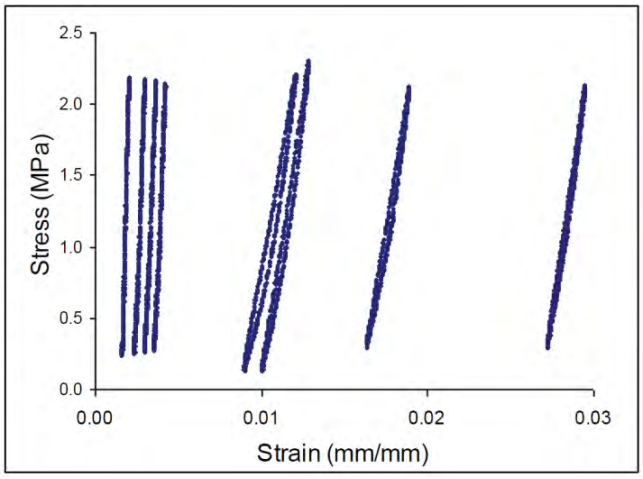

Figure 1 – *Stress-strain curves obtained with compressive fatigue test from a male trabecular bone (only cycles number 7000, 10000, 25000, 80000, 100000, 136000, 150000, 170000 and 195000 are shown).*

The use of nanomaterials in the control and prevention of Legionella bacteria

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Abstract

In this investigation we intend to perform innovative work to reduce or even tackle a serious problem affecting people's health, air contamination by Legionella.

Legionnaires´ disease or legionellosis arose due to human alteration of the environment, Legionella species can be found in aquatic environments, water warm and hot, and humid places, such as cooling towers, spas, among others. This is an infectious disease caused by bacteria belonging to the genus Legionella. The mode of transmission varies with the variety of bacteria but the disease is usually transmitted through inhalation of aerosols as carriers of small bacteria to the lungs, allowing its deposition in the alveoli. The infection caused by Legionella pneumophila is known to have two different forms, the legionnaire's disease is a form of pneumonia caused by an acute bacterial infection and Pontiac fever is a less severe form of the disease, causes a flu-like acute pain. The rate of infection is increases in people with impaired (insufficient) immune systems. This means that healthy young people are rarely infected with Legionella. Factors that increase the likelihood(probability) of infection by disease are: tobacco, certain cancers, excessive alcohol consumption, age over 50 years, among others.

To reduce the multiplication of Legionella pneumophila and the associated risk of Legionnaires' disease should be taken measures to prevent and control physical, chemical and microbiological, in order to promote and maintain clean surfaces of water systems and air. One of the systems used for purification of air filtration consists in the separation and capture of particles of any kind. The filters need technical requirements that are a balance between three key parameters: the filter efficiency, pressure drop and the durability of the filter. The level of filtration efficiency is determined by the field of application, or with the ability to obtain clean air. The fibrous filtration media is the most used in air filtration, these media may be cellulosic or non-synthetic fabrics. Textiles are used in a variety of filtration processes, wet and dry, allowing both increase the purity of the filtered material and the recovery of solids.

The aim of this work is develop an air purification system by producing anti-microbial agents to fight Legionella assets. For the development of this project will be used new materials (nano-materials) and textile structures (nonwovens) bioactive so as to control or prevent the action of these microbial agents.

Joining technologies for hybrid materials consisting of sheet metal and carbon fibre reinforced plastics

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Abstract

The attempt for enhanced security, lean production and the need for a more economical consumption of resources during the process of production and operation of automobiles require new approaches and new solutions in lightweight construction. One promising approach is the combination of sheet metal and fibre reinforced plastics (FRP) to form hybrid structures. Here, the wall thickness of the metallic structure is reduced and afterwards a local FRP reinforcement is applied to heavily loaded sections of the construction. In this way it is possible to produce load-adapted lightweight structures that are up to 35 % lighter than mere steel solutions.

Current research work within the scope of a collaborative research project at the Chair for Automotive Lightweight Construction (LiA) at the University of Paderborn concentrates on the investigation of hybrid materials and their processing. In particular, new manufacturing processes like the prepreg press technology are developed to make hybrid components attractive and available for automotive mass production. This includes, for example, trimming process chains, reducing cycle times and thus a reduction of process steps and costs. This is amongst other things realised by using the epoxy matrix resin as an adhesive.

Current research results in the field of hybrid materials are presented in this paper. First, the prepreg press technology to manufacture automotive structural components in hybrid design is illustrated. In particular the advantages of this technology compared to conventional processing methods for FRP are highlighted, such as a reduction of cycle times from more than 15 minutes to below 5 minutes. Afterwards the joining of the steel and the FRP component by the use of the epoxy matrix resin as an adhesive is discussed. The bonding was investigated on the basis of relevant standards and various influences on the bond strength, such as different surface treatments, curing times and temperatures. In addition, results for the bond strength are compared to a typical epoxy-based crash-stable adhesive for automotive applications. It is shown that the bond strength of conventional prepreg epoxy matrix resins reaches over 90 % of the strength of structural adhesives for quasistatic shear tensile loads. Besides a significant reduction of costs could be realised by skipping an additional bonding process. Hereafter it is pointed out that the orientation of fibres in the boundary layer has a decisive influence on the bond strength of prepreg pressed samples. Finally, appropriate solutions and design informations are proposed.

Evaluation of Modelling Capability of KPA Welding Fabrication of Thin Structures of Titanium Alloy

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Abstract

Finite element simulation of welding process allows accurate predictions of welding distortions, residual stresses, etc., of complex structures which occur due to the non-uniform heating and cooling cycles during the welding process. This in turn can significantly reduce the need for physical trials and manufacturing cost and can therefore improve the manufacture accuracy. In addition, such numerical simulations can be used to provide useful input to assist the design and structural integrity assessment.

This paper reports the results of a comprehensive study related to the development and validation of a modelling capability for keyhole plasma arc welding (KPA), Figure 1, of thin structures. The material considered in this work is a typical aero-engine casing material Ti-6Al-4V alloy. The finite element software SYSWELD was used to model the welding process. A welding sequence optimization procedure, based on a genetic algorithm approach, has been developed to minimize the welding induced distortions, Figure 2. Experimental validation is carried out based on the comparison of predicted and measured results of thermal histories, weld pool sizes, distortions and residual stresses. The results of case studies of thin sheet structures were used to demonstrate the applicability and efficiency of the modelling capability developed. Proposals for future exploitation and improvement of the technique developed are addressed.

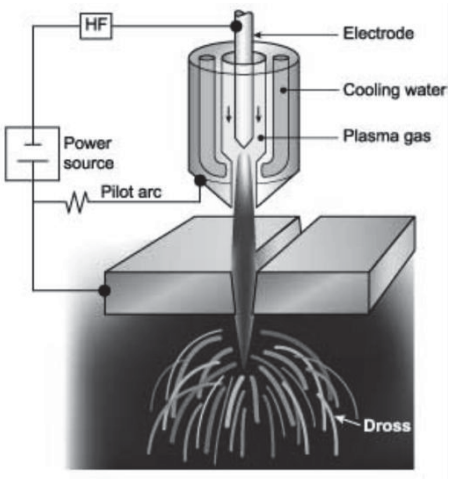

Figure 1 Schematic diagram of KPA welding

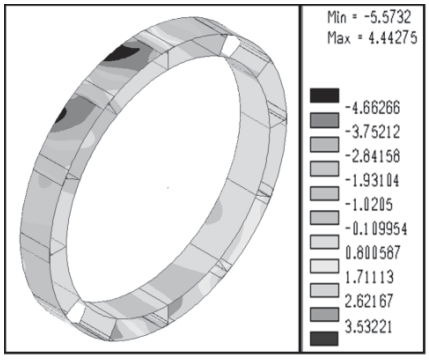

Figure 2 Global model distortion of a casing

A novel test method for durability evaluation of an adhesively bonded joint between CFRP and CFRP sandwich components under surface loading

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Abstract

Due to the damage-free pretreatment of the joined components and the areal load distribution adhesive bonding is an eminently suitable joining technology for composite materials. Adhesively bonded joints between fibre reinforced composite parts are commonly used, such as in wind turbine rotor blades or in the ship building and automotive industry. In consequence of the increasing number of Carbon Fibre Reinforced Polymere (CFRP) components adhesively bonding becomes more and more relevant also for aircraft structures.

This work deals with the durability evaluation of an adhesively bonded joint between a CFRP frame rib and a CFRP sandwich shell of an aircraft component under surface loading. Therefore a water pressured test rig introducing the surface load into the test component by an elastomeric membrane was designed via numerical simulation of the membrane draping behavior resulting into the calculation of the needed water volume for the test. Afterwards the components were tested under quasi-static and fatigue loading. During the tests thermography measurements as well as novel Structural Health Monitoring techniques (Comparative Vacuum Monitoring) were used to determine the damage initiation and propagation. Complementary to the experimental investigations numerical calculations were performed using a cohesive zone model to simulate the rib debonding behavior.

Accuracy of adhesive joint strength predictions by finite element analyses

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Abstract

Adhesively-bonded joints are extensively used in several fields of engineering, as an easy and efficient method to join components. Cohesive Zone Models (CZM) have been used in the last decade for the strength prediction of adhesive joints, as an add-in to Finite Element (FE) analyses that allows simulation of damage growth within bulk regions of continuous materials or interfaces between different materials, by consideration of energetic principles. Compared to conventional FE, a much more accurate prediction s achieved, as this technique provides an accurate representation of the entire failure process. A useful feature of CZM is that different shapes can be developed for the cohesive laws, depending on the nature of the material or interface to be simulated, allowing a faithful representation of the fracture processes. The triangular and trapezoidal CZM shapes are most commonly used for strength prediction of typical structural materials. This work studies the influence of the CZM shape (Fig. 1) used to model a thin adhesive layer in single-lap adhesive joints, for an estimation of its influence on the strength prediction under different material conditions. As a result of this study, some conclusions were established to assess the importance of using a CZM shape for a given adhesive that faithfully represents its behaviour, under different material behaviours (a brittle and a ductile adhesive were tested). The viability of using a triangular CZM that is easier to use, without compromising the accuracy of the results, was also assessed.

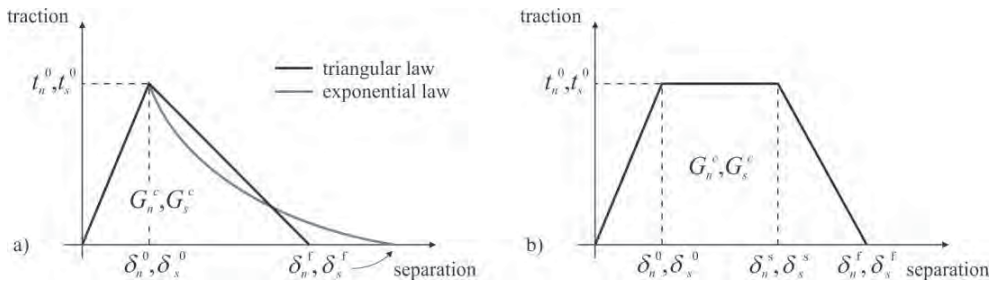

Figure 1 - *CZM laws with triangular, exponential and trapezoidal shapes available in Abaqus®*

Study and optimization of the single-lap and T-peel joints using the finite element method

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Abstract

The most traditional methods of joining components are bolting, riveting, welding or adhesive-bonding. Adhesive bonds don't require holes and distribute the load over a larger area than mechanical connections. However, they tend to develop a peak tension pullout and shear stresses near the ends of the overlap because of the differential effect of the substrates deformation and asymmetry of the transmitted load. As such, premature rupture may occur, especially a brittle adhesive is used. In addition, adhesive bonds are very sensitive to surface treatment, operating temperature, moisture, aging and other environmental extremes. The combination of adhesive bonding with spot welding allows some competitive advantages to traditional adhesive bonds and also increased resistance (especially for brittle adhesives), decreased weight, increased stiffness, better resistance to tearing and fatigue, and easier manufacturing because a positioning device during curing of the adhesive is not required. This technique dates back to the 70's [1], although the process remained unattended until recently due to lack of systematic theoretical and experimental research. Nonetheless, in the last decade this scenario progressively changed through the accomplishment of experimental and theoretical investigations [2]. This paper presents an experimental and numerical study of T-peel hybrid joints (adhesive and spot welded) subjected to tensile and bending loads, compared to traditional adhesive and spot welded joints. The numerical work will be performed by the finite element method (FEM) package Abaqus® using cohesive damage models (CDM) for the simulation of damage onset and growth within the adhesive bond and spot welds. A parametric study will be held considering a few design variables, which will allow the optimization of hybrid joints. As a result of this study, the advantages of the proposed hybrid technique are discussed, compared to the purely bonded or welded equivalent joints, and some design principles are proposed in light of the studied optimization variables. The suitability of the chosen predictive technique for the specific purpose of designing bonded/welded joints is also assessed.

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Mixed-Mode Fracture Toughness Determination Using Non-conventional Techniques

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Abstract

The focus of this work is to understand the effect of the adhesive thickness and adhesive ductility on the mixed mode loading of Double Cantilever Beam joints. After some extensive testing in pure modes (I and II) some other tests with a ratio of mixed modes using SLB, ADCB and the Dual Actuator Loading frame were done to obtain enough data to support the design of an apparatus that uses DCB steel specimens to obtain the fracture envelope for adhesives.

Using this apparatus, a ductile polyurethane adhesive and a fragile epoxy were characterized and the fracture envelopes are presented for different thicknesses. A data reduction scheme that does not take into account the crack length (a) is also presented.

Mechanical Characterization of a High Temperature Epoxy Adhesive

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Abstract

It is well known that in order to properly design a joint the adhesive behaviour has to be characterized. Thus, to determine the stresses and strains in adhesive joints in a variety of configurations, it is necessary to know the adhesive mechanical properties. In this work, the performance of a high temperature epoxy adhesive has been studied through bulk specimens and adhesive joint tests. In order to obtain a tensile strength profile of the adhesive, bulk specimens of cured adhesive were produced and tested in tension at RT and high temperatures (100ºC, 125ºC, 150ºC). The Thick Adherend Shear test (TAST) was performed in order to measure the shear properties. The double cantilever beam (DCB) for opening pure mode I loading and the end-notched flexure (ENF) for sliding pure mode II loading were used to get the mode I and II adhesive fracture toughness. In addition, single lap joints (SLJs) were fabricated and tested to assess the adhesives performance in a joint. Results showed that the failure loads of both the bulk test and joint test specimens vary with temperature and this needs to be considered in any design procedure.

FSW – Most influent welding parameters and their interactions on joints mechanical properties

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Abstract

Previous studies that can be found in literature about Friction Stir Welding are not based on optimized parameters. Trying to fill that blank, this project is focused on the optimization and prediction of the joint strength using the Taguchi technique to determine the interactions between parameters in order to achieve improved welding solutions. This paper presents the first mechanical results obtained for that frame.

A Taguchi array was chosen to define the best combinations of parameters to perform the FSW experiments. The selected parameters were: the rotational speed (A), welding speed (B), tilt angle (C), probe distance from the root surface (D), and shoulder/probe diameters ratio(E), each one with three levels. Butt joints of AA6082-T6 aluminium were performed and the mechanical properties possible to obtain from tensile tests were analyzed, tensile and yield strengths and elongation. After the welding trials, and respective analysis it was observed that the interaction between tool rotational speed and welding speed and as individual parameter the probe/shoulder diameter ratio are the most influent for the mechanical properties response, Figure 1.

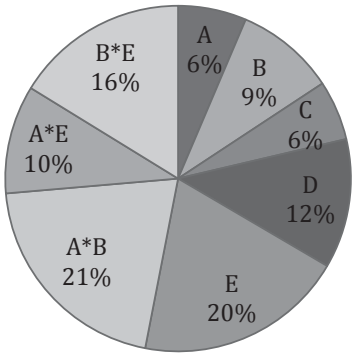

Figure 1 – *Parameters influence for mechanical properties*

Acknowledgments

This work was supported by the FCT project PTDC/EME-TME/114703/2009. Dr. Moreira acknowledges POPH – QREN-Tipologia 4.2 – Promotion of scientific employment funded by the ESF and MCTES. The collaboration of Mr. José Almeida during the welding trials is gratefully acknowledged.

The enriched natural neighbour radial point interpolation method for the analysis of crack tip stress fields

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Abstract

Meshless Methods were created and developed in order to answer to some drawbacks and limitations found in the Finite Element Method (FEM). In the last few years meshless methods enlarge their application field, and are today a competitive and alternative numerical method in structural analysis. In this work a meshless method is used to study several solid mechanics benchmark examples considering an elasto-static analysis. Generally, in meshless methods the nodes discretizing the problem domain can be randomly distributed, since the field functions are approximated within a flexible influence domain rather an element, and the influence domains may and must overlap each other, in opposition to the no-overlap rule between elements in the FEM. In this work a radial interpolator meshless method is used to analyse the stress field around the crack tip. In this meshless method the nodal connectivity and the background integration mesh, totally dependent on the nodal mesh, are achieved using mathematic concepts, such as Voronoï Diagrams and the Delaunay tessellation. The obtained interpolation functions, used in the Galerkin weak form, are constructed with the Radial Point Interpolators and possess the delta Kronecker property. Due the organic procedure employed to impose the nodal connectivity the displacement and the stress field are smooth and accurate, as it is possible to observe in figure 1.

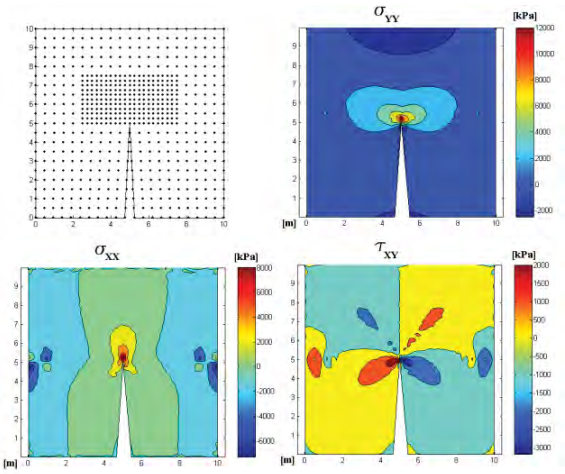

Figure 1 - *Domain nodal discretization and obtain stress field*

Use of Isogeometric Analysis to simulate a sheet metal forming operation using the Finite Element code LS-DYNA

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Abstract

A new computational method called Isogeometric Analysis (IGA) [1] is currently being developed, with the goal of integrating computer aided design (CAD) and finite element analysis (FEA). The main idea behind its development is to reuse the mathematical description for the geometry produced in the design stage (CAD) to conduct the numerical analysis studies (FEA). Currently, Non-Uniform Rational B-Splines (NURBS) are being used as basis functions in many isogeometric analyses [2], since this geometrical representation is one of the most widely used in engineering design systems.

This work presents the basic ideas of an isogeometric analysis and gives a short introduction to NURBS basis functions. Using the Finite element package LS-DYNA, a sheet metal forming simulation is obtained, using the recently developed isogeometric capabilities of the software. The results are compared with the normal preocedure, using a standard finite element simulation, based on Lagrange polynomials and some conclusions are presented.

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Coupled-Multi Scale Models: Advantages and limitations

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Abstract

The behavior of a material is inevitably a reflection of its micro-structure. As a consequence, the development of new materials, which has to satisfy the increasingly severe requirements, demands the manipulation of their microstructure. The numerical tools are a vital ally on the developement and desing of performant structures where the selection of the material is itself a huge challenge. Conventionally, the modeling of different materials has been performed by means of continuous constitutive models where the characterization of the main effects which take place at their microstructure is established by differential equations. Although remarkable results were achieved with this procedure, in widely heterogeneous materials this approach has shown clear limitations. As a result, a new approach has recently aroused a great interest either in scientific or industrial communities: coupled multi-scale models. This approach stands out due to the fact that, each spatial domain where relevant and crucial effects occurs (void growth, crack propagation, damage, phase transformation among several others) may be conveniently modeled by means of a representative volume element (RVE). By definition, the deformation of the micro-structure is driven by a macroscopic deformation tensor and, the stress at the macro-scale is a consequence of the global behavior of the RVE. However, the use of this formulation requires some caution since, there are some pathologies that this kind of models suffers. In general these pathologies are inherent with the definition of the RVE as well as with the mesh dependence that these models suffers. In this context, the main goal of this paper is twofold: point out the limitations of coupled multi scale models and suggest some improvements in order to circumvent them.

Application of Finite element formulation to solid-shell structures for the analysis of time reduction

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Abstract Finite element analysis of shell structures has proved its reliability for years. Enhanced assumed strain method [1] is one of the unique techniques in finite element method by which a number of internal variables could be added to a strain field to enhance the field or which leads to more deformation modes. This technique has proved effective in preventing volumetric and transverse shear locking in 3-D shell elements [2]. The technique yields productive results even with coarse meshes (lesser number of elements during analysis), which can result in reducing the manipulation time.
The EAS formulation is shown in equation (1),

$$\boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}_d + \boldsymbol{\varepsilon}_\alpha = \begin{bmatrix} \mathbf{B}_d^e & \mathbf{B}_\alpha^e \end{bmatrix} \begin{bmatrix} \mathbf{d}^e \\ \boldsymbol{\alpha}^e \end{bmatrix} \quad , \qquad (1)$$

where, $\mathbf{B}_d^e$ is the standard strain displacement differential operator and $\mathbf{B}_\alpha^e$, is the enhanced variable field ($\boldsymbol{\alpha}$).

The EAS element was developed based on formulation referred in equation (1) and tested with static structures which were then validated with established examples [3]. This has proved that EAS element helps in obtaining the results with minimum number of elements (coarse mesh) and thus helps in reducing the conception time. The analysis has also thrown light into the effects of the different mesh sizes.
In the present work the developed EAS element is applied to shells for a dynamic analysis on the structures. A few other elements were also tested with the structures to compare the results. Shell structures with different mesh sizes, starting from a coarse mesh to a finer mesh are modelled and tested with the element. The structure is initially excited between a particular frequency range and the maximum displacement is found. The maximum displacement of the shell structures with different mesh sizes has provided a good outcome to understand the behaviour of the finite element formulation being tested. Then the element is applied to a real automobile part provided by the BMW for a dynamic analysis. The automobile part was also meshed with different mesh sizes and was tested with the same procedure. The time consumed for the analysis for both the simple shell structure and for the automobile part is calculated. From the results it has been proved that EAS is compatible with the shell structures for a dynamic analysis and has yielded significant results

Acknowledgements

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The authors truly acknowledge Dr.Cremers from BMW for providing the automobile part for the research.

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A primal closest point projection algorithm for Magnesium alloys

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Abstract

Due to their high strength-to-weight ratio, Magnesium alloys offer a great potential to reduce weight and have been widely used in the automotive and aerospace industries. However, their hexagonal close packed (HCP) crystallographic structure, with a c/a ratio of 1.624, has a very limited number of active slip systems at room temperature, which are not enough to accommodate plastic deformation without the activation of twinning. The polar nature of deformation twinning promotes a strong asymmetry between yielding in tension and compression, usually known as strength differential effect (SD). Conventional phenomenological constitutive models of plasticity [1, 3] such as Hill et al., Barlat et al., Karafillis and Boyce (1993) fail to capture this unconventional mechanical behavior. Cazacu and Plunkett [2] have proposed generic yield criteria, by using the transformed principal stress, to account for the initial plastic anisotropy and SD effect simultaneously. In this contribution, the Cazacu model is briefly described and implemented using a primal Closest Point Projection Method (CPPM) within an implicit quasi-static finite element environment. The accuracy of the algorithm is assessed by means of iso-error maps.

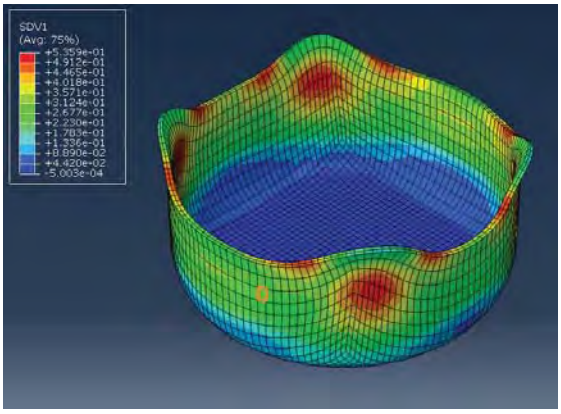

Figure 1 – *Plastic strain distribution of cup drawing test*

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Application of CDM models for the simulation of the mechanical behavior of Ti-6Al-4V titanium alloy under different loading conditions.

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Abstract

Simulation of the mechanical behavior of materials is a key factor in the design process, especially when critical components are investigated. Focusing of failure phenomenon, continuum damage mechanics (CDM) is one of the most promising frameworks in the field of failure models for ductile materials. Therefore in this paper, a calibrated CDM model has been applied using a commercial FE software, by means of dedicated routine, to simulate failure behavior during experimental tests. These have been carried out on the simple specimens but with several loading conditions. The tested material is Ti-6Al-4V titanium alloy which is multiphase titanium alloy commonly used for high stressed and low weight critical components. The data obtained by numerical simulations were critically compared with the results obtained from experimental tests in order to verify the performance of the calibrated CDM model.

Analysis of elastic fields in an isotropic medium containing a penny-shaped crack by the Ritz method

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Abstract

In the crack growth analysis, the Stress Intensity Factor (SIF) is a fundamental prerequisite. In the present study, the mode I stress intensity factor (SIF) of three-dimensional penny-shaped crack is obtained in an isotropic elastic cylindrical medium with arbitrary dimensions under arbitrary loading at the top of the cylinder, by the semi-analytical method based on the Rayleigh-Ritz method. This method that is based on minimising the potential energy amount of the whole of the system, gives a very close results to the previous studies. Defining the displacements (elastic fields) by hypothetical functions in a defined coordinate system is the base of this research. So for creating the singularity conditions at the tip of the crack the appropriate terms should be found.

Keywords: Three-dimensional cracks; Penny-shaped crack; Stress intensity factor; Fracture mechanics; Ritz method

Evaluation of Hysteretic Behavior of Eccentrically Braced Frames With Zipper-Strut Upgrade

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Abstract

This paper describes the seismic behavior of the upgraded eccentrically braced frames (EBF) using zipper-struts which connect the mid-point of shear links in all stories. By adding zipper struts to the conventional EBF system, the unbalanced shear force is distributed among all stories due to the added continuity between shear links. This results in the extension of the structure's displacement capacity in Immediate Occupancy and Life Safety acceptance criteria. Moreover, a noticeable delay occurs until shear links experience enough rotation to meet Collapse Prevention acceptance criteria. Consequently, the structure may experience higher levels of displacement in comparison to the conventional EBFs.

The numerical modeling of the zipper-strut-equipped model is conducted using finite-element method software and the hysteretic behavior of the system is analyzed under cyclic load, with the goal of evaluating the continuity of the rotation between shear links, along with close observation of shear behavior of the links throughout the steps of the analysis. The hysteretic response of the upgraded EBF system is compared to that of a similar prototype without the new modification. The interaction of shear link and zipper-struts are also studied in this paper. Furthermore, the prototypes are subjected to nonlinear static (Pushover) analysis in two configurations; one with moment-resisting connections and one with pinned connections. The acceptance criteria of these structures are studied and the extension of these zones is determined. Finally, the increase of ductility coefficient for the prototypes with zipper-strut is observed, which is calculated in accordance with the maximum displacement of the structure at Collapse Prevention stage.

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