Book of Abstracts

3rd International Conference on Structural Integrity

Funchal, Madeira, Portugal

2 – 5 September, 2019

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10:40-11:10		COFFEE-BREAK				COFFEE-BREAK				COFFEE-BREAK			
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17:30-18:00										CLOSING SESSION			
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19:15-23:00										CONFERENCE BANQUET			

Technical Program

August 24th, 2019 version

Monday, 2nd September 2019

MON, 09:00 - 09:30	OPENING SESSION	Room Lisboa
Welcome to Participants **(Conference Co-Chairs)** Welcome Address **Representative of Regional Government**		

MON, 09:30 - 10:05	PLENARY LECTURE I	Room Lisboa
The Latest Development of Bio-sourced Composites for GREEN Aviation **Prof. Xiaosu YI** University of Nottingham Ningbo, Aviation Industry of China, China Chair: Pedro Moreira (INEGI, Portugal)		

MON, 10:05 - 10:40	PLENARY LECTURE II	Room Lisboa
Progress in Solid State Joining of Metals and Alloys **Oystein Grong** Norwegian University of Science and Technology, Norway Chair: Paulo Tavares (INEGI, Portugal)		

Monday, 10:40 - 11:10	**COFFEE-BREAK**	**Lounge**

Mon	Session 1A 11:10-12:40	Room Lisboa
TOPIC: Symposium A - Fatigue Crack Growth – experimental, theoretical and numerical approach Chair: Grzegorz Lesiuk		
Ref:	Title and Author (s)	
006	Acquiring in situ fatigue crack growth curves by a compliance method for micro-bending beams to reveal the interaction of micro-cracks with grain boundaries Florian Schaefer; Patrick Gruenewald; Jonas Rauber; Michael Marx; Christian Motz	
020	Numerical analysis of pitting corrosion fatigue in floating offshore wind turbine foundations Behrooz Tafazzolimoghaddam; Ali Mahboob Hamedany; Ali Mehmanparast; Feargal Brennan; Kamran Nikbin; Catrin Davies	
041	Description of mixed mode fatigue (I+II, I+III) crack growth in constructional S355/P355NL1 steels using J-integral approach Grzegorz Lesiuk; Dariusz Rozumek; Jose A.F.O. Correia; Abílio de Jesus; Zbigniew Marciniak; Michał Smolnicki	
103	Plasticity induced crack closure distribution along crack front Tomáš Oplt; Marek Šebík; Filippo Berto; Luboš Náhlík; Pavel Pokorný; Pavel Hutař	
104	Influence of humidity on near-threshold fatigue crack propagation in steels used in railway or civil industry Pavel Pokorný; Tomáš Vojtek; Stanislav Seitl; Luboš Náhlík; Pavel Hutař	
051	Propagation of long fatigue cracks in Ti6Al4V alloy produced by direct metal laser sintering Ludvík Kunz; Radomila Konečná; Gianni Nicoletto	

Mon	Session 1B 11:10-12:40	Room Sidney
TOPIC: SHM / NDT Chair: Luís Borrego		
Ref:	Title and Author (s)	
233	New monitoring solutions for large civil engineering structures - Project MEGE Francisco Barros; Luís Oliveira Santos; Paulo J. Tavares; Maria Graça Neves; Rui Capitão; Conceição Juana Fortes; Duarte Ferreira; Francisco Fernandes; Elsa Franco; Décio Rodrigues	
094	Vibration-based fault detection for flywheel condition monitoring Takanori Hasegawa; Tetsuji Ogawa; Teppei Nakano	
226	Digital image correlation with a moving camera using structure from motion calibration Francisco Barros; Pedro Sousa; Paulo Tavares; Pedro Moreira	
153	Geometry Acquisition and 3D Modelling of a Wind Tower using 3D Laser Scanning Technology Behzad V. Farahani; Francisco Barros; Mihai Popescu; Pedro J. Sousa; Paulo J. Tavares; Pedro Moreira	
184	Development of LED-based illumination system for high-speed digital image correlation Pedro Sousa; Fernando Carneiro; N. Ramos; Paulo Tavares; Pedro Moreira	
185	Application of 3D electronic speckle pattern interferometry for analysis of thermal response in printed circuit boards Pedro J. Sousa; Fernando Carneiro; N. Viriato Ramos; Francisco Barros; Mário Vaz; Paulo Tavares; Pedro Moreira	

Mon	Session 1C 11:10-12:40	Room Berlin
TOPIC: Symposium G - Failure analysis Chair: Virginia Infante		
Ref:	Title and Author (s)	
080	Failure Mechanisms in High-Strength Eutectoid and Duplex Stainless Steel Wires Subjected to Tensile and Transverse Loads M. Iordachescu; M. de Abreu; A. Valiente	
101	Analysis of cracks propagated in a tee pipe fitting C. Medrea; E. Pappa; D. Papageorgiou; C. Stergiou	
102	Microscopic examination of a fan blade supporting system premature fractured D. Papageorgiou; H. Bravos; C. Medrea	
146	Verification / Structural Analysis of Industrial Equipment - Identification and characterization of structural damages with hardness tests and microstructural examination – structural verification Paulo Pereira; Nuno Ramos; Mário Vaz	
147	Computational simulation of a forklift mast - Static and dynamic verification of the operation of a truck with identification of critical voltages and real center of mass. Paulo Pereira; Nuno Ramos; Mário Vaz	
166	Hydraulic tube inspection of a Boeing aircraft Freitas, M.; Infante, V.	

Mon	Session 1D 11:10-12:40	Room Rio de Janeiro
TOPIC: Symposium B - High Strain Rate Testing of Engineering Materials and Structures Chair: José Xavier		
Ref:	Title and Author (s)	
016	Energy Absorption Capabilities of Periodic Cellular Mechanical Metamaterials for Improved Crashworthiness Belinda Babu Joseph; Giuseppe Catalanotti; Zafer Kazancı; Brian Falzon	
039	An improved technique for high speed impact simulation verification Doubrava Radek; Oberthor Martin; Vích Ondřej	
204	Identification of high strain rate behaviour of wood based on an inertial impact test Filipa Cunha; Lloyd Fletcher; José Xavier; Fabrice Pierron	
205	High strain rate compressive behaviour of wood on the transverse plane José Xavier; Filipe Gomes; Hannes Koeber	
212	Investigation of a test method for the determination of strain rate-dependent material properties of high-performance fibers Reimar Unger; Andreas Nocke; Chokri Cherif	
215	An experimental and numerical investigation of the crushing behavior of 2D woven CFRP Formula 1 crash structures D. Dalli; L. Varandas; G. Catalanotti; B. Falzon; S. Foster	

Monday, 12:40 - 14:00	LUNCH	Restaurant

Mon	Session 2A 14:00-15:30	Room Lisboa	Mon	Session 2B 14:00-15:30	Room Sidney	Mon	Session 2C 14:00-15:30	Room Berlin	Mon	Session 2D 14:00-15:30	Room Rio de Janeiro
TOPIC: Symposium A - Fatigue Crack Growth – experimental, theoretical and numerical approach / Symposium D - International Symposium on Structural Integrity of iron&steel Bridges (ISSI-Bridges 2019) Chair: Grzegorz Lesiuk/ Stéphane Sire			TOPIC: Symposium B - High Strain Rate Testing of Engineering Materials and Structures Symposium E - NDE methods and techniques serving structural integrity assessment Chair: José Xavier / Peter Trampus			TOPIC: Symposium G - Failure analysis Chair: Virginia Infante			TOPIC: Manufactruing – LBW / FSW / LSP Chair: Alexopoulos Nikolaus		
Ref:	Title and Author (s)		Ref:	Title and Author (s)		Ref:					
042	Fatigue Behaviour of Bolted Connections Made of Thin Steel Plates. Experimental study Vítor Gomes; Abílio de Jesus; Miguel Figueiredo; C. Souto; António Fernandes; Grzegorz Lesiuk; José Correia		216	Intralaminar fracture toughness and crack resistance curves for FRPs under high rate loading P. Kuhn; G. Catalanotti; J. Xavier; H. Koerber		149	Investigation of tank collapse – analysis of support elements collapses, fracture characterization and weld seams, static and dynamic analysis Paulo Pereira; Nuno Ramos; Mário Vaz		129	Assessment of the Mechanical Integrity of a 2 mm AA6060-T6 Butt Weld Produced Using the Hybrid Metal Extrusion & Bonding (HYB) Process – Part II: Tensile Test Results Lise Sandnes, Luca Romere, Filippo Berto, Torgeir Welo, Øystein Grong	
043	Mean stress effect and fatigue crack closure in material from old bridge erected in the late 19th century Grzegorz Lesiuk; Stephane Sire; Muriel Ragueneau; Jose Correia; Monika Duda; Abilio de Jesus		007	Non-destructive composites monitoring through the magnetic microwire inclusions A. Zhukov; A. Allue; P. Corte-León; K. Gondra; M. Ipatov; J. Blanco; V. Zhukova		210	Influence of Structural Failure on Crash or Post-Crash movement for Power Two Wheelers Vehicles Kenny Santos; João Dias		087	Fracture mechanical behavior of different low alloyed titanium thin sheets welded by Yb:YAG fibre laser for T-ducts in bleed air systems Stefan Riekehr; Volker Ventzke; Manfred Horstmann; Sabine Wagner; Werner Beck; Nikolai Kashaev	
044	Study of the influence of the load ratio on the high cycle fatigue behaviour of double shear riveted joints Stéphane Sire; Bernard Espion; Muriel Ragueneau		008	Development of stress-sensitive magnetic microwires for magnetoelastic sensors V. Zhukova; P. Corte-Leon; M. Ipatov; J.M. Blanco; M. Churyukanova; A. Zhukov		167	Study of the mechanical strength of the wings of a domestic frying pan Freitas, M.; Infante, V.		138	Optimization of autogenously laser beam welded AA 2198 alloy joints T.N. Examilioti; J. Enz; S. Riekehr; N. Kashaev; B. Klusemann; N. Alexopoulos	
067	Crack-Detection in old riveted steel bridge structures Lars Sieber; Ralf Urbanek; Jürgen Bär		056	NDT integrity engineering – a new discipline Peter Trampus		201	Failure Analysis of the Upright Component of FST08e Suspension System Karas, H.; Martins, T.; Sousa, L.; Dias, J.; Infante, V.; Freitas, M.		145	Effect of filler wire on the fracture toughness of laser beam welded 2198 joints V. Avgeri; T. Examilioti; N. Kashaev; D. Karanikolas; S. Kourkoulis; N. Alexopoulos	
112	Very high cycle tests of high strength steels S355 J0 and S355 J2 Jan Klusák; Stanislav Seitl		182	Displacement analysis of rotating RC helicopter blade using coupled CFD-FEA simulation and digital image correlation Pedro J. Sousa; Francisco Barros; Paulo J. Tavares; Pedro M. G. P. Moreira		202	Numerical and Experimental Analysis of the Suspension Connection Area of a Formula Student Monocoque Chassis Formiga, J.; Sousa, L.; Infante, V.		150	Friction stir welding of polymers, recent developments Shayan Eslami; Paulo Tavares; Pedro Moreira	
136	Examining the use of Digital Image Correlation for Detecting Distortion-induced Fatigue Cracks in Steel Bridges William Collins; Caroline Bennett; Jian Li; Elaina Sutley; Hayder Al-Salih; Mary Juno		053	Acoustic Emission-Based Similarity Analysis: A Baseline Convergence Algorithm Andra Stancu; Linghao Zhou; Slim Soua		148	Investigation of crane collapse – analysis of fractured bonding elements, center of mass and natural frequencies (dynamics) Paulo Pereira; Nuno Ramos; Mário Vaz		093	Investigation of the fatigue crack retardation caused by laser shock peening induced residual stresses using a multi-step simulation and experiments S. Keller; M. Horstmann; N. Kashaev; B. Klusemann	

Monday, 15:30 - 16:00	COFFEE-BREAK	Lounge

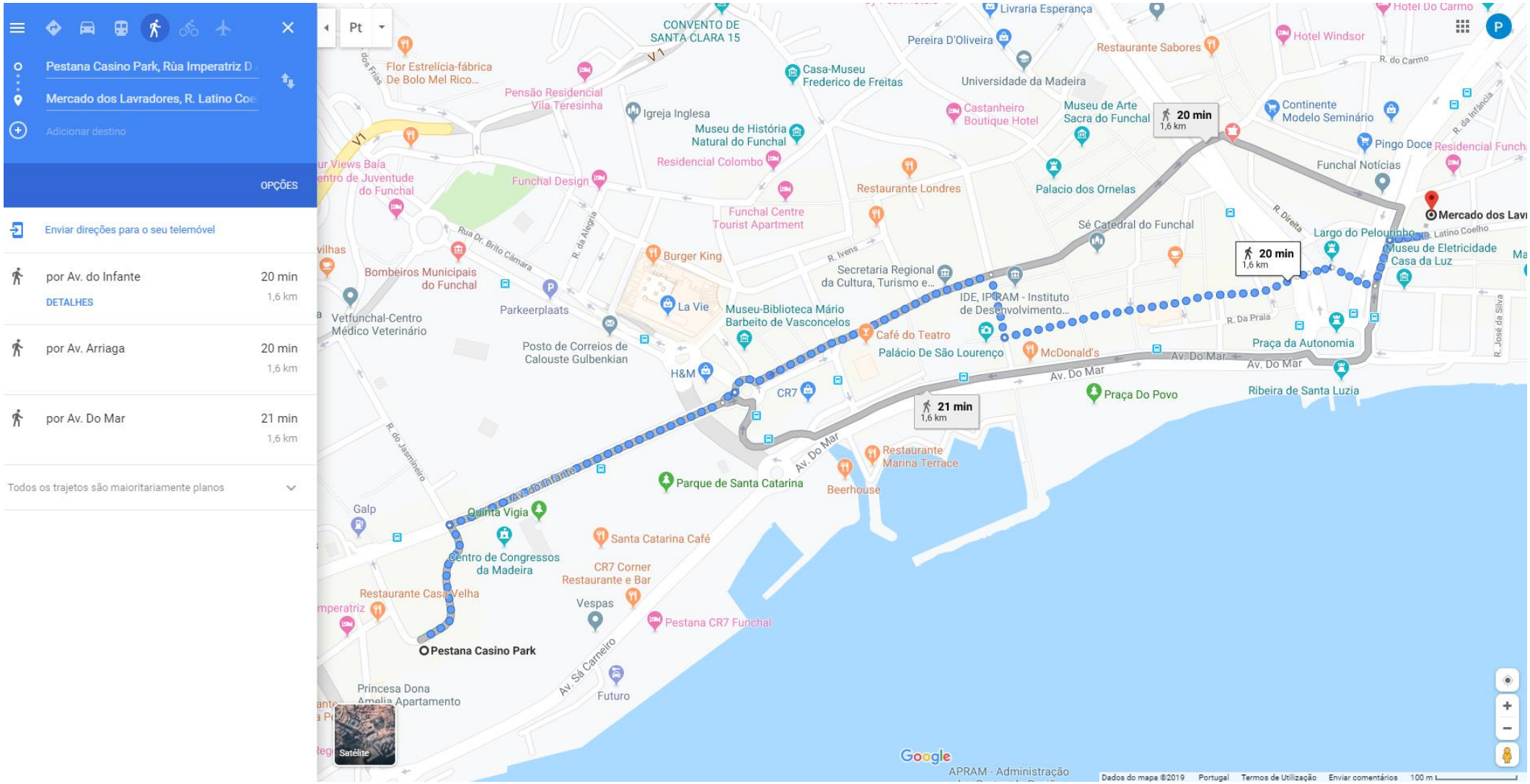
Mon	Session 3A 16:00-17:30	Room Lisboa
TOPIC: Fatigue Chair: Luís Reis		
Ref:	Title and Author (s)	
040	Load Sequence Effects on the Fatigue and Structural Durablity of Components under Service Load-Time Functions Matthias Hell; Rainer Wagener	
083	The study of plastic deformation at fatigue crack tip during biaxial loading A. Vshivkov; A. Iziumova; O. Plekhov	
096	Fatigue tests of materials with the controlled energy parameter amplitude Z. Marciniak; D. Rozumek; R. Brighenti; G. Lesiuk; J. Correia	
200	Prediction of fatigue life of a Portuguese Air Force aircraft Barros, T.; Serrano, B.; Infante, V.; Sousa, L.; Antunes, P.; Moura, A.	
133	Mechanical behavior of structural steel under biaxial low-cycle fatigue at room and elevated temperatures A. Ilinykh; A. Lykova	
213	Evaluation in Fatigue Life of 300 M Steel After Laser Carburizing a Plasma Nitriding Abdalla, A.; Santos, D; Vasconcelos, G.; Scheid, V.; Silva, D.	

Mon	Session 3B 16:00-17:30	Room Sidney
TOPIC: Symposium C - Structural Health Monitoring Chair: Hernani Lopes		
Ref:	Title and Author (s)	
024	Monitoring mass changes using nanoresonator sensors Antonino Morassi; Michele Dilena; Marta Fedele Dell'Oste; José Fernández-Sáez; Ramón Zaera	
156	Application of spline interpolation to speckle shearography measurements for damage identification A. Arco; I. Figueiras; L. Pedroso; J. V. Araújo dos Santos; H. Lopes	
197	Crack closure measurement in Al2024 compact tension specimen subjected to random loading Belen Moreno; Pablo Lopez-Crespo; Manuel Carrera; Jaime Dominguez	
198	Estimation of the plastic zone in fatigue through the thickness based on synchrotron diffraction data Manuel Carrera; Pablo Lopez-Crespo; Belen Moreno; Yee-Han Tai; John Yates; Philip Withers	
199	SHM TB30, Numerical Study of an Aircraft Structural Condition Martins, T.; Infante, V.; Sousa, L.; Antunes, P.; Moura, A.; Serrano, B.	
223	Identification of material properties of a laminated plate from measurements of natural frequencies and nodal rotations H. Lopes; J. Araújo dos Santos; A. Katunin	

Mon	Session 3C 16:00-17:30	Room Berlin
TOPIC Railway Chair: Mário Vaz		
Ref:	Title and Author (s)	
084	Continuous Monitoring and Evaluation of Railway Tracks: System Description and Assessment João Morais; Carlos Santos; Paulo Morais; André Paixão; Eduardo Fortunato; Francisco Asseiceiro; Paula Alvarenga; Luís Gomes	
152	3D Laser Scanning System for Geometry Documentation on a Rock Railway Tunnel Behzad V. Farahani; Francisco Barros; Pedro J. Sousa; Pedro P. Cacciari; Paulo J. Tavares; Marcos M. Futai; Pedro Moreira	
154	Design of an Automated Inspection System to Monitor the Defects in Railway tunnels Behzad Farahani; Francisco Barros; Pedro Sousa; Paulo Tavares; Pedro Moreira	
078	Continuous Monitoring and Evaluation of Railway Tracks: Proof of Concept Paulo Morais; João Morais; Carlos Santos; André Paixão; Eduardo Fortunato; Francisco Asseiceiro; Paula Alvarenga; Luís Gomes	
054	Effect of manufacturing residual stress on the fatigue life of railway wheels for heavy-haul transportation Eduardo Lima; Thiago Martins; Aureliano Santos	

Mon	Session 3D 16:00-17:30	Room Rio de Janeiro
TOPIC: Manufacturing - Welding / Adhesive / LSP Chair: Ana Barbosa		
Ref:	Title and Author (s)	
117	Integral Structures of the Future: Recommendations from Materials Engineering Nikolai Kashaev; Volker Ventzke; Norbert Huber	
070	Determination of Fracture Modes in Novel Aluminum-Steel Dissimilar Resistance Spot Welds Liting Shi; Jidong Kang; David Sigler; Amberlee Haselhuhn; Blair Carlson	
214	Fatigue Performance of Friction Stir Weld-Bonded Al-Mg joints Ricardo Maciel; Tiago Bento; Daniel Braga; Lucas da Silva; Pedro Moreira; Virgínia Infante	
095	Tensile strength and failure of dissimilar friction stir welded joints between 6061-T6 and 2014-T6 aluminum alloys Madhav Raturi; Ashu Garg; Anirban Bhattacharya	
085	Effect of temperature and fatigue loading condition on shear lap strength of an epoxy adhesive reinforced with micro cork particles Ana Barbosa; Alireza Akhavan-Safar; Lucas da Silva; Majid Ayatollahi	
009	Analytical model for estimation of energy release rate at mode I crack tip in bi-material of identical steels joined by an over-matched weld interlayer Sunil Bhat	

Monday, 18:15 - 19:30	WELCOME RECEPTION	
COCKTAIL RECEPTION Courtesy, Funchal City Hall Funchal, “Mercado dos Lavradores”		



Tuesday, 3rd September 2019

TUE, 09:30 - 10:05	PLENARY LECTURE III	Room Lisboa
Structural integrity and durability of polymer composites: Achievements and challenges **Constantinos Soutis** Aerospace Research Institute, University of Manchester, UK Chair: Aleksandar Sedmak		

TUE, 10:05 - 10:40	PLENARY LECTURE IV	Room Lisboa
Fatigue & fracture crack paths generated by manufacturing-induced microstructural & strength anisotropy in cold drawn pearlitic steels: ***(a) In the conceptual frame of Maurits Cornelis Escher and Johann Sebastian Bach; (b) An Orteguian approach and a tribute to Fray Luis de León's "decíamos ayer"*** **Jesus Toribio** University of Salamanca, Spain Chair: Paulo Tavares		

Tuesday, 10:40 - 11:10	**COFFEE-BREAK**	**Lounge**

Tue	Session 4A 11:10-12:40	Room Lisboa
TOPIC: Symposium I - Green and Recycled Composite Materials / Composites Chair: Carmen Sguazzo		
Ref:	Title and Author (s)	
119	Results of the ECO-COMPASS EU-China Project Jens Bachmann; Xiaosu Yi	
179	High Strain-Rate Behavior of Carbon-Epoxy Composites for Lightning Strike Protection Sahand Shamchi; Carmen Sguazzo; Anurag Singh; Nuno Ramos; Xiaosu Yi; Z. Zhao; P. Moreira	
180	Hydrothermal Ageing Performance of Nano-clay Modified Flax Fiber Fabric Reinforced Epoxy Plates Guijun Xian; Anni Wang	
192	Oxidative Treatment of Multi-Walled Carbon Nanotubes and its Effect on the Mechanical and Electrical Properties of Green Epoxy based Nano-Composites Anurag Singh; Carmen Sguazzo; Carlos F.R.A.C. Lima; Luis M.N.B.F. Santos; Jorge M. Reis; Pedro M. G. P. Moreira; Paulo J. Tavares	
032	Microscopic Damage Size in Fiber-Reinforced Polymer-Matrix Composites: Quantification Approach via NDT Measurements Andreas Brunner; Philipp Potstada; Markus Sause	
131	Research of fatigue durability construction GFRP under increased temperatures Lobanov Dmitrii S.; Staroverov Oleg A.	

Tue	Session 4B 11:10-12:40	Room Sidney
TOPIC: Symposium F - Degradation Mechanisms in the Operation of Metal Structures Chair: Vladimír Chmelko		
Ref:	Title and Author (s)	
030	Degradation of microstructure and properties of an AISI 316L steel tube after more than 100,000 hours usage at 640°C in a petrochemical industry Flavio de Moraes; Sandro Junior; Ronald Plaut; Angelo Padilha	
098	Austenitic cast iron resistant against the abrasive material degradation Berta, I.; Pokusová, M.	
099	Degradation mechanisms in the operation of pressure pipelines Garan, M.; Šulko, M.	
100	Safety of pressure pipe operation with corrosive defect Chmelko, V.; Biro, D.	
111	Laboratory method for simulating hydrogen assisted degradation of gas pipeline steels Hryhoriy Nykyforchyn; Oleksandr Tsyrulnyk; Olha Zvirko	
128	On the Hydrogen State and Its Role in the Stress Corrosion Cracking of AZ31 and ZK60 Magnesium Alloys Evgeniy Merson; Vitaliy Poluyanov; Pavel Myagkikh; Dmitri Merson; Alexei Vinogradov	

Tue	Session 4C 11:10-12:40	Room Berlin
TOPIC: Concrete Chair: Paulo Lobo		
Ref:	Title and Author (s)	
208	Soft computing-based techniques for concrete beams shear strength Danial J.Armaghani; George D. Hatzigeorgiou; Chrysoula Karamani; Athanasia Skentou; Ioanna Zoumpoulaki; Panagiotis G. Asteris	
074	Embedded ultrasonic transmission sensors and signal processing techniques for structural change detection in the Gliwice bridge Joyraj Chakraborty; Andrzej Katunin; Piotr Klikowicz; Marek Salamak	
022	Evaluation of damage in concrete from structures affected by internal swelling reactions – A case study João Custódio; António Ribeiro	
122	Fracture Resistance of Alkali Activated Concrete under the Mixed Mode I/II Load Conditions Petr Miarka; Stanislav Seitl; Vlastimil Bílek	
137	The influence of polygonal cavity on fracture behaviour of concrete Michal Vyhlídal; Jan Klusák	
125	Influence of the SMA constitutive model on the longitudinal seismic response of RC bridges Pedro Nunes; Paulo Silva Lobo	

Tue	Session 4D 11:10-12:40	Room Rio de Janeiro
TOPIC: Manufacturing - Additive / Residual stresses Chair: Nikolai Kashaev		
Ref:	Title and Author (s)	
031	Notch fatigue behavior of Inconel 718 produced by selective laser melting Radomila Konecna; Gianni Nicoletto	
110	Microstructural and environmental effects on the fatigue crack propagation of AM TiAl6V4 alloy specimens L.Borrego; J. Ferreira; J. de Jesus; J. Costa; C. Capela	
187	Mechanical Properties of 18Ni-300 maraging steel manufactured by LPBF Thomas Simson; Jürgen Koch; Jakub Rosenthal; Miloslav Kepka; Miroslav Zetek; Ivana Zetková; Gerhard Wolf; Petr Tomčík; Jiři Kulhánek	
010	A review of present status and challenges of using additive manufacturing technology for offshore wind applications A. Ermakova; A. Mehmanparast; S. Ganguly	
144	Assessment of computational weld mechanics concepts for estimation of residual stresses in welded box structures J. Zhu; M. Khurshid; Z. Barsoum	
231	Mechanical performance of Additive Manufacturing: Fundamentals, results and a real case study Marc Gardon; Fernando Lasagni	

Tuesday, 12:40 - 14:00	LUNCH	Restaurant

Tue	Session 5A 14:00-15:30	Room Lisboa
TOPIC: Composites Chair: Carmen Sguazzo		
Ref:	Title and Author (s)	
132	Phenomenological characteristics structural features research obtained during fibrous plastics standard tests Elena Strungar; Andrey Babushkin; Anna Babushkina; Oleg A. Staroverov; Dmitrii Lobanov; Evgenia Feklistova	
165	Enhanced algorithm for damage location on composite material Guillermo Azuara; Eduardo Barrera; Mariano Ruiz	
183	Experimental study of the damage accumulation in composite materials and ceramic coatings by using of acoustic emission technique Ekaterina Zubova; Elena Strungar; Dmitriy Lobanov; Valery Vildeman	
196	Study of the Regularities of Postcritical Behavior and Failure of Specimens in the Tests of Composite Materials Tretyakov M.P.; Wildemann V.E.; Lobanov D.S.	
222	Experimental studies of 3D woven composites interweaving types effect on the mechanical properties of a polymer composite material Elena Strungar; Evgenia Feklistova; Andrey Babushkin; Dmitrii Lobanov	
015	Finite Element Models Describing the Failure in Steel Cable-Reinforced Rubber Composites Siegfried M. Frankl; Martin Pletz; Alfred Wondracek; Clara Schuecker	

Tue	Session 5B 14:00-15:30	Room Sidney
TOPIC: Testing / Structural analysis Chair: Alexopoulos Nikolaus		
Ref:	Title and Author (s)	
012	Fatigue life of a bus structure in normal operation and in accelerated testing on special tracks Miloslav Kepka; Miloslav Kepka Jr.; Jaroslav Václavík; Jan Chvojan	
026	Correlation between fractographics aspects and stress intensity factor in very high cycle fatigue M. Pereira; M. Teixeira; F. Darwish	
060	Notch tensile strength of carbon fiber/epoxy composite plate with a center hole under static and cyclic loading W. Alhazmi; A. Abd-Elhady; A. Abu-Sinna; S. Mousa; H. Sallam	
075	Flexural Behavior of RC Beams Strengthened with Bolted and Bonded Aluminum Alloy Omar Abuodeh; Jamal A. Abdalla; Rami A. Hawileh	
076	Use of Aluminum Alloy Plates as Externally Bonded Shear Reinforcement for R/C Beams Jamal A. Abdalla; Adi Abu-Obieda; Rami A. Hawileh	
162	An Estimation of Ramberg-Osgood Constants for Materials with and without Luder's Strain Using Yield and Ultimate Strengths Daniel Kujawski; Pranav Patwardhan; Rajprasad Nalavde	

Tue	Session 5C 14:00-15:30	Room Berlin
TOPIC: Civil/Concrete Chair: João Custódio		
Ref:	Title and Author (s)	
164	Numerical analysis of shear crack propagation in a concrete beam without transverse reinforcement G. Rombach; A. Faron	
003	Influence of silica fume on mechanical and fracture properties of high performance concrete Piotr Smarzewski	
035	Reinforcement of building plaster by waste plastic and glass Kennouche Salim; Abdelli Houssam; Amrane Belaid; Hami Brahim	
046	Shear Strengthening of Reinforced Concrete Beams Using CFRP Wraps Rami A. Hawileh; Haya H. Mhanna; Jamal A. Abdallah	
143	Seepage and dam deformation analyzes with statistical models: support vector regression machine and random forest Ahmed Belmokre; Mustapha Kamel Mihoubi; David Santillan	
224	Behavior of short concrete cylinders partially confined with GFRP composites Moussaoui Ba; Bouamra Yb; Ait Tahar K	

Tue	Session 5D 14:00-15:30	Room Rio de Janeiro
TOPIC: Fatigue / Crack Growth Chair: Paulo Tavares		
Ref:	Title and Author (s)	
021	Material Mechanics of Crack Growth in Structural Dynamics Feiyang He; Muhammad Khan; Behzad Zai	
058	A Review of Fatigue Performance of Bolted Connections in Offshore Wind Turbines Sharda Lochan; Ali Mehmanparast; John Wintle	
073	Fatigue assessment of amplitude-modulated non-stationary random vibration loading Arvid Trapp; James Makua; Peter Wolfsteiner	
038	DCPD based detection of the transition from short to long crack propagation in fatigue experiments on the aluminum alloy 7475 T761 Meike Funk; Jürgen Bär	
107	Fatigue behavior of different geometry scaffolds for bone replacement R. Baptista; M. Guedes	
108	An algorithm for fatigue crack growth applied to mixed and biaxial mode loadings R. Baptista; V. Infante; M. Freitas	

Tuesday, 15:30 - 16:00	COFFEE-BREAK	Lounge

Tue	Session 6A 16:00-17:30	Room Lisboa
TOPIC: Composites Chair: Jidong Kang		
Ref:	Title and Author (s)	
017	Numerical analysis of auxetic yarns with composite matrix interaction Michał Kwietniewski; Danuta Miedzińska	
168	Optimization of the Homogenization Characterization of Thin Hybrid Composites Rui B Ruben; Virgínia Infante; José FA Madeira; Filipa Moleiro; Sofia Teixeira de Freitas	
178	Research on Bio-based Thermosets at NIMTE: From High Thermomechanical Properties to Functionalization Xiaoqing Liu	
190	Mechanical Characterization of Sandwich Composites with Embedded Sensors Joana Sousa; João Marques; Madalena Garcia; Pedro Amaral; Virgínia Infante	
048	Analysis of transverse cracking in [0/90]2s composite laminates loaded in flexure with asymmetrical environmental conditions M. Khodjet-kesba; A. Benkhedda; E.A. Adda Bedia; B. Boukert	
011	Hygrothermal stresses Analysis of Thick Composite Plates Using High Order Theory under a Fick Concentration Distribution B.Boukert; A.Benkhedda; E.B Adda; M.Khodjet Kesba	
235	Post-fire Performance of Novel Flame Retardant Composites Xiaoling Liu	

Tue	Session 6B 16:00-17:30	Room Sidney
TOPIC: Testing / Structural Analysis Chair: Daniel Braga		
Ref:	Title and Author (s)	
130	Fatigue damage analysis of offshore wind turbine monopile weldments Romali Biswal; Ali Mehmanparast	
028	Analysis of the structural girders of a crane for the license renewal of a BWR nuclear power plant Juan Cruz-Castro, Edgar Hernández-Palafox, Luis Héctor Hernández-Gómez, Gilberto Soto-Mendoza, Yunuén López.Grijalba, Pablo Ruiz-López	
161	An interactive cloud-based fatigue analysis tool Daniel Kujawski	
082	Fracture toughness and Small Punch Test: review of methodologies and new proposal R. Lacalle; J.A. Álvarez; D. Andrés; B. Arroyo; J.A. Sainz-Aja	
121	High-Strain-Rate Loading of Friction Stir Weld-Bonded Joints Daniel Braga; P. Rosa; Sahand Pourhassan; P. Moreira; Lucas da Silva; V. Infante	
218	An experimental study on the fracture behavior of different aluminium alloys subjected to ballistic impact Pradipta Jena; K. Kumar; R. Mandal; A. Singh	

Tue	Session 6C 16:00-17:30	Room Berlin
TOPIC: Civil/Soil Chair: Paulo Lobo		
Ref:	Title and Author (s)	
160	Stability Analysis of Compression Member on Elastic Supports Ivan Baláž; Yvona Koleková; Lýdia Moroczová	
209	Offshore wind bolted flange connections: Effects of tightening sequence on preload Jarryd Braithwaite; Ali Mehmanparast	
013	Numerical analysis of time-dependent deformation effects on preload relaxation behavior of offshore wind turbine bolted connections A. Mehmanparast	
063	Numerical simulation of soil stability during artificial freezing Zhelnin M.; Kostina A.; Panteleev I.; Plekhov O.; Levin L.	
118	The effect of cryogenic suction on the monitoring data of ice barrier formation in a porous water-saturated soil Plekhov O.A.; Panteleev I.A.; Kostina A.A.; Levin L.V.	
120	The experimental investigation of freezing and thawing process in water-saturated soil based on FBG sensor system Prokhorov A.; Kostina A.; Zhelninn M.; Plekhov O.	

Tue	Session 6D 16:00-17:30	Room Rio de Janeiro
TOPIC: SHM Chair: Mário Vaz		
Ref:	Title and Author (s)	
071	Registration of local damage based on the use of fiber-optic strain sensors and numerical simulation results Kosheleva N.A.; Matveenko V.P.; Serovaev G.S.	
177	Lighting Pole Health Monitoring for Predictive Maintenance Pavel Steinbauer; Zdenek Neusser; Ivo Bukovsky; Miloš Neruda	
027	Landing Gear Structural Health Monitoring (SHM) Chad Forrest; Clint Forrest; Doug Wiser	
158	Environmental Testing of FBG Sensor System for Structural Health Monitoring of Building and Transport Structures Kristýna Čápová; Lukáš Velebil; Jan Včelák; Milan Dvořák; Ladislav Šašek	
163	Structural Integrity Analysis and Life Estimation of a Gas Turbine Bladed-Disc Shahnawaz Ahmad; Ganesh Pawar; N S Vyas; Vikas Kumar	
062	Determination of dissipated energies during fatigue tests on Copper and AA7475 with Infrared Thermography Jürgen Bär; Luca Seilnacht; Ralf Urbanek	

Wednesday, 4th September 2019

WED, 09:30 - 10:05	PLENARY LECTURE V	Room Lisboa
Micromechanical Modelling of Weldment Cracking **Aleksander Sedmak** Belgrade University, Serbia Chair: Oystein Grong		

WED, 10:05 - 10:40	PLENARY LECTURE VI	Room Lisboa
Corrosion susceptibility of aeronautical Al-Li alloys **Alexopoulos Nikolaos** University of the Aegean, Greece Chair: Constantinos Soutis		

Wednesday, 10:40 - 11:10	**COFFEE-BREAK**	**Lounge**

Wed	Session 7A 11:10-12:40	Room Lisboa
TOPIC: Composites Chair: Carmen Sguazzo		
Ref:	Title and Author (s)	
191	Numerical Modelling of Flexural Behaviour of Cork-Core Sandwich Composites Bogdan Sandu; João Marques; Madalena Garcia; Virgínia Infante; Pedro Amaral	
227	Experimental and numerical studies on the behaviour of polymer-matrix fibre-reinforced composites subjected to soft impact loading Haibao Liu; Jun Liu; Cihan Kaboglu; Hui Chai; Xiangshao Kong; Bamber R.K. Blackman; Anthony J. Kinloch; John P. Dear	
059	Mixed Mode Crack Growth in Functionally Graded Material Under Three-Point Bending S. Mousa; A. Abd-Elhady; A. Abu-Sinna; T. Enab; W. Alhazmi; H. Sallam	
139	Simulation of a Cementitious Matrix with Carbon Nanostructure Reinforcement S. Anastopoulos; F. Givannaki; P. Papanikos; Z. Metaxa; N. Alexopoulos	
134	Fatigue Behavior of Carbon/Epoxy Non-crimp Fabric Composites for Automotive Applications Trevor Donald Sabiston; Bin Li; Jidong Kang; Jie Liang; Carlos Engler-Pinto	
033	Review of Elastomeric Materials for Application to Composites Reinforced by Auxetics Fabrics Michał Kwietniewski; Danuta Miedzińska	

Wed	Session 7B 11:10-12:40	Room Sidney
TOPIC: Symposium H - Multiaxial fatigue and VHCF: experimental, theoretical and numerical approach Chair: Luís Reis		
Ref:	Title and Author (s)	
123	Transverse load influence on tensile fatigue resistance of high-strength steel wires for structural applications in civil engineering M. De Abreu; M. Iordachescu; A. Valiente	
135	Mechanical Treatment of Crack-Arrest Holes under Distortion-induced Fatigue William Collins; Caroline Bennett; Jian Li; Luke Bridwell	
220	VHCF behavior of a high strength crankshaft steel M.C. Teixeira; P. R. Costa; M.V. Pereira; M. Freitas; L. Reis	
221	Fatigue testing of cruciform specimens under VHCF L. Reis; P. R. Costa; D. Montalvão; M. Freitas	
229	Fatigue Testing at 1000Hz Testing Frequency Markus Berchtold; Ingbert Klopfer	
023	Durability of Hypotrochoidal Polygon-Shaft-Hub Connections under Rotating Bending with Static Torsion Sebastian Vetter; Erhard Leidich; Masoud Ziaei; Marcus Herrmann; Alexander Hasse	

Wed	Session 7C 11:10-12:40	Room Berlin
TOPIC: Civil Chair: Paulo Lobo		
Ref:	Title and Author (s)	
089	Static Elasticity Modulus Analysis of Coating Mortars Ana Marques; João Morais; Carlos Santos; Paulo Morais; Maria Veiga	
124	Water tanks construction using post-tensioned precast concrete Pedro Palma; Manuel Sardinha; Paulo Lobo; António Magalhães	
181	Experimental measurement of bridge deflection using Digital Image Correlation Pedro J. Sousa; Francisco Barros; Paulo Lobo; Paulo J. Tavares; Pedro M. G. P. Moreira	
207	Compressive strength of natural hydraulic lime mortars using soft computing techniques Maria Apostolopoulou; Danial Armaghani; Asterios Bakolas; Maria Douvika; Antonia Moropoulou; Panagiotis Asteris	
057	Corrosion and tensile behavior of 316L stainless steel concrete reinforcement in harsh environments containing a corrosion inhibitor S. Tsouli; A. Lekatou; C. Nikolaidis; S. Kleftakis; I. Tragazikis; T. Matikas	
186	Classification of multiple acoustic-emission features for the safety evaluation of a road bridge under service load and environmental changes Imane Bayane; Joyraj Chakraborty; Andrzej Katunin; Eugen Brühwiler	

Wednesday, 12:40 - 14:00	LUNCH	Restaurant

Wed	Session 8A 14:00-15:30	Room Lisboa
TOPIC: Fracture / Testing Chair: Daniel Braga		
Ref:	Title and Author (s)	
055	Analysis of the crack location in notched steel bars with a multiple DC potential drop measurement Moritz Hartweg; Jürgen Bär	
061	Fatigue Behavior of AA2198 in Liquid Hydrogen Jürgen Bär; Alexander Metzger; Nico Pouvesle; Bernhard Strauß; Nathan Bamsey; Thomas Rohr	
069	Effect of Biaxiality on Engineering Critical Assessments Konstantinos Kouzoumis; Isabel Hadley; Mahmoud Mostafavi	
091	Compatibility of fracture toughness results in the upper shelf region Pavel Konopik; Martin Rund; Sylwia Rzepa; Jan Dzugan; Melzer Daniel	
113	Investigation of Structural Integrity of Composite Materials using Wavelet Packet Transform Claudia Barile; Caterina Casavola; Giovanni Pappalettera; Carmine Pappalettere; Paramsamy Vimalathithan	
034	Different Failure Mechanisms in Keyed Shaft-Hub Connections under Dynamic Torque Load Felix Kresinsky; Erhard Leidich; Alexander Hasse	

Wed	Session 8B 14:00-15:30	Room Sidney
TOPIC: Materials Chair: Paulo Tavares		
Ref:	Title and Author (s)	
115	Fatigue life prediction of Polymethyl methacrylate (PMMA) polymer under random vibration loading C Okeke; A Thite; J Durodola; M Greenrod	
206	Experimental study of the influence of the strain-stress state on the jerky flow in metals and alloys Tatyana Tretyakova; Valery Wildemann	
116	Dynamic response and fatigue life of Vacuum cast Polyurethane polymer material C P Okeke; S J Brown; M T Greenrod; R C Lane; A N Thite	
232	Incremental Hole Drilling Residual Stress Measurement in Thin Aluminum Alloy Plates Subjected to Laser Shock Peening J.P. Nobre; C. Polese; S. van Staden	
140	Electrochemical analysis of the corrosion resistance of aeronautic Al-Cu-Li 2198-T8 alloy in different corrosion solutions Dimitris Georgoulis; Christina Charalampidou; Carsten Blawert; Mikhail Zheludkevich; Nikolaos Alexopoulos	
211	Effects of residual stresses and localised strain-hardening on the fracture of ductile materials H. Coules; G. Horne	

Wed	Session 8C 14:00-15:30	Room Berlin
TOPIC: LBW/FSW/ Additive /residual/LSP Chair: Alexopoulos Nikolaus		
Ref:	Title and Author (s)	
151	Friction stir spot riveting of thermoplastic composites Shayan Eslami; P Moreira	
170	Effect of Heat Treatment on Additively Manufactured AISI 18Ni300 Steel using Selective Laser Melting Sahand Shamchi; L. Borrego; J Ferreira; P Moreira	
018	Residual Stress Management - RSM: An Indispensable Tool in Structural Integrity J. Kleiman	
019	Latest developments in nondestructive testing of residual stresses in welded structures by ultrasonic method J. Kleiman; Y. Kudryavtsev	
086	Experimental and finite element analysis of progressive failure in friction stir welded AA6061-AA7075 joints Ashu Garg; Madhav Raturi; Anirban Bhattacharya	
064	Fatigue crack growth behavior of laser-shock processed 2024-T3 aluminum C. Baptista; M. de Lima; R. Riva; R. Siqueira	

Wednesday, 15:30 - 16:00	COFFEE-BREAK	Lounge

Wed	Session 9A 16:00-17:30	Room Lisboa
TOPIC: Materials Chair: Virginia Infante		
Ref:	Title and Author (s)	
188	On instabilities of growing bi-material interfaces Wureguli Reheman; Per Ståhle	
045	Effect of Pretreatment on Interface Stability and Morphology of Ni/Al Hybrid Foams by in situ Microcantilever Fracture Experiment Anne Jung; Jutta Luksch; Florian Schaefer; Christian Motz	
052	Investigation of mechanical properties and microstructure of X60 line-pipe steel Jan Kec; Ivo Černý; Adam Poloch; Barbora Kyselá; Miloslav Poupa; Romana Pavelková; Jiří Janovec	
066	The most frequent failure causes and modes in super ferritic stainless steels: are they really super? C. Azevedo; A. Padilha	
079	Microstructure evolution and creep strength of new-generation ODS alloys with a high volume fraction of nanooxides Petr Dymáček; Jiří Svoboda; Luděk Stratil; Vít Horník	
228	Effect of medium carbon steel microstructure on tensile strength and fatigue crack growth Blaoui Mossaab; Zemri Mokhtar; Arab Amin	

Wed	Session 9B 16:00-17:30	Room Sidney
TOPIC: Modelling Chair: Francisco de Melo		
Ref:	Title and Author (s)	
169	Numerical Simulations of Fatigue Crack Growth in a Steam Turbine Rotor Blade Groove Jiří Kuželka; Martin Nesládek; Maxim Lutovinov; Josef Jurenka; Milan Růžička; Martin Rund; Petr Měšťánek	
029	Numerical analysis of the BWR-5 beltline region containing a crack postulated for an extended period of operation Salatiel Pérez-Montejo; Pablo Ruiz-López; Gilberto Soto-Mendoza; Alejandra Armenta-Molina; Abraham Villanueva-García; Luis Héctor Hernández-Gómez	
077	Numerical model for the stress field ahead of a crack in elastoplastic regime J. Pascon; M. Torres; C. Baptista	
203	Numerical analysis of the influence of the last cycle scheme on plasticity induced crack closure D. Camas; F. Antunes; B. Moreno; A. Gonzalez-Herrera	
072	Numerical Modeling of the Capillary in the Bragg Grating Area, Ensuring Uniaxial Strain of Embedded Fiber-Optic Strain Sensors Serovaev G.S.; Matveenko V.P.; Kosheleva N.A.; Fedorov A.Yu.	
155	Ductile Failure Prediction of an Al-Mg Alloy: Experimental and Computational Validation Behzad Farahani; Rui Amaral, Francisco de Melo; Paulo Tavares; Pedro Moreira, Abel Santos	

Wed	Session 9C 16:00-17:30	Room Berlin
TOPIC: Fracture Chair: Luís Borrego		
Ref:	Title and Author (s)	
037	Effect of pre-strain on cyclic plastic behaviour of 7050-T6 aluminium alloy R. Branco; L. Borrego; J. Costa; J. Ferreira	
081	Environmentally-Assisted Cracking of Type 316L Austenitic Stainless Steel in Low Pressure Hydrogen Steam Environments Jaromír Janoušek; Fabio Scenini; Liberato Volpe; Anna Hojná; Mary Grace Burke	
088	Towards a Generalized Methodology for Structural Integrity Calculations of Large-Scale Pressure Vessels Tamás Fekete	
090	Correlation between steel initiation toughness and arrest toughness determined from small-scale mechanical testing Jessica Taylor; Ali Mehmanparast; Philippa Moore; Rob Kulka	
230	Elastoplastic deformation and destruction of structural steel under biaxial loading conditions Anastasiya V. Lykova, Artem V. Ilinikh, Valery E. Wildemann, Tatyana V. Tretyakova	
109	Creep-ratcheting-fatigue life prediction of bainitic 2.25Cr1MoV steel Zizhen Zhao; Dunji Yu; Xu Chen	

Wednesday, 17:30 – 18:00	CLOSING SESSION	Room Lisboa
Conference Organizing Committee		

Wednesday, 19:15 - 23:00	BANQUET	

CONFERENCE BANQUET
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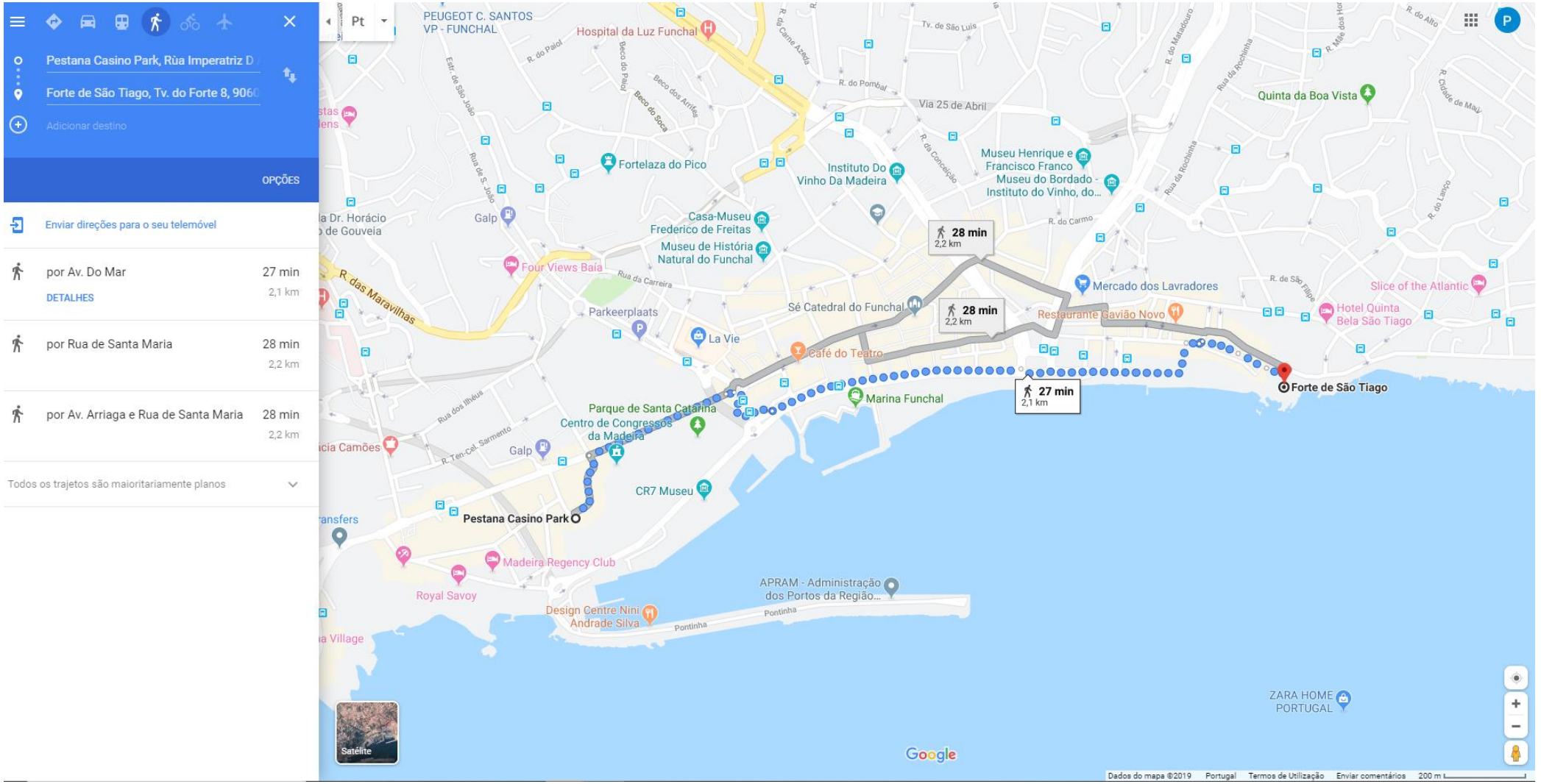

Thursday, 5th September 2019

Thursday, 09:00	**Conference Tour**	departure at the hotel
"Madeira Sight Seeing, Wonders of the Est – Santana"		

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ICSI 2019 The 3rd International Conference on Structural Integrity

Editorial

Pedro Moreira*, Paulo J. Tavares

INEGI – Institute of Science and Innovation in Mechanical and Industrial Engineering, Porto, Portugal

Peer-review under responsibility of the ICSI 2019 organizers.

Research activity in Structural Integrity has seen an emerging increase in recent years and spread throughout a number of exciting areas. ICSI focuses on all aspects and scales of structural integrity. This ranges from basics to future trends, with special emphasis on multi-scale and multi-physics approaches, and applications to new materials and challenging environments. Current research topics in the realm of Structural Integrity targeted by ICSI2019 include, but are not limited to Fracture and Fatigue, Stress Analysis, Damage Tolerance, Durability, Crack Closure, Joining Technologies, Nanomechanics and Nanomaterials, Ageing, Coatings Technology, Environmental Effects, Structural Health Monitoring, New materials, Surface Engineering, Structural Integrity in Biomechanics and many other exciting research topics.

In 2019, ICSI made an effort to return to the delegates a part of their dedication and enthusiastic support from the previous editions, in the shape of increased visibility to the conference and scientific impact. ICSI2019 therefore launched a number of invitations to prominent researchers all over the globe to lecture on their own research fields, such as Prof. Prof. Xiaosu Yi; Prof. Aleksander Sedmak; Prof. Alexopoulos Nikolaos; Prof. Constantinos Soutis, and; Prof. Øystein Grong. In view of the success of the ICSI2017 thematic symposia, ICSI2019 has also been organized into a general track and thematic symposia. Apart from the publication of the proceedings in Procedia Structural Integrity and a special issue in Theoretical and Applied Fracture Mechanics, special issues were also offered in Applied Composite Materials and Engineering Failure Analysis, highly relevant journals in the field of Structural Integrity.

The response to these efforts has been outstanding: Nine symposia were proposed and accepted for organization; the number of abstract submissions was kept at a similar level to 2017 with 203 communications approved for oral communication from a total of 234 received abstracts, and 131 full papers accepted for publication in the conference proceedings.

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Peer-review under responsibility of the ICSI 2019 organizers.

The biennial ICSI conferences, at the end of summer, were planned to be a referential source of inspiration for the researchers in the field that want to keep updated on the latest developments from reference researchers around the globe. The conference has seen an unprecedented growth in volume and quality and we welcome the reader to judge the excellence of the conference by himself and whether he should attend the next ICSI in 2021.

Above all, the organizers believe the ICSI conferences disseminate excellent research and share worthwhile and beneficial knowledge for the enhancement of science and the prosperity of our society, and therefore actively contribute to the preservation and sustainability of our world.

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Pedro M. G. P. Moreira
Paulo J. S. Tavares
INEGI – Institute of Science and Innovation in Mechanical and Industrial Engineering

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João Custódio, LNEC, Portugal

, Influence of silica fume on mechanical and fracture properties of high performance concrete

Piotr Smarzewski

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Abstract The use of silica fume (SF) in combination with a superplasticizer is a simple way to obtain high performance concrete (HPC). The mechanical properties and durability of HPC concerning the harmful chloride and sulfate ions are improved. Nevertheless, researchers mention some disadvantages of using silica fume in HPC such as the decrease of plasticity during the concrete production and the increase of shrinkage during the concrete curing. Researchers disagree about the optimal content of SF. To some of these the content is about 15%, whereas for others the increase in mechanical properties may reach for 30% of cement replacement by SF.

The main aim of this study is to determine the fracture energy of HPC containing SF. The article presents the investigation on changes of the mechanical properties including compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, and fracture energy of six HPC caused by the addition of SF. Additions of SF into the HPC were 0%, 5%, 10%, 15%, 20% and 25% by weight of cement content. The water/binder ratio was 0.25. The fracture energy were calculated by dividing the work of fracture by the initial area in accordance with RILEM TC 50-FCM recommendations. The use of SF increased all tested mechanical properties of concrete. The study indicates that the mechanical properties of HPC were improved to a great extent at 28 days when cement used in concrete was replaced by SF. The SEM results shown that adding of SF to HPC significantly changes the microstructure. It was noticed that the narrowest microcracks and the smallest pores in the interfacial transition zone (ITZ) between the paste and aggregate followed in the HPC containing 10% SF. The findings suggest that SF can effectively replace cement. Nevertheless, it is recommended that the replacement should not exceed 10%.

, Acquiring *in situ* fatigue crack growth curves by a compliance method for micro-bending beams to reveal the interaction of micro-cracks with grain boundaries

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all authors: Materials Science and Methods, Saarland University, Saarbruecken, Germany

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Abstract To understand the interaction of dislocations with microstructural obstacles it is necessary to find test methodologies which are able to resolve the interaction of single or few defects with obstacles like interfaces. Therefore, the investigation of micro specimens has been established over the years as a suitable method to test the influence of microstructural features on the mechanical response. While quasi-static loading of micro specimens has been carried out extensively in the past decade and gave powerful insights on the mechanical behaviour at small scales, cyclic loading and fatigue crack experiments still provide a challenge.

In order to check the possibility to systematically initiate and monitor fatigue crack growth rates in micro specimens, we cyclically loaded micro bending beams made of a nickelbase superalloy. Furthermore, for grain boundaries of differing type we checked if the crack growth curves are suitable to measure crack-microstructure interactions. The fatigue cracks showed a deceleration when approaching the grain boundaries followed by an abrupt acceleration, which is in accordance to macroscopic experiments and connected to dislocation or slip transfer from the plastic zone of the crack through the grain boundary. Furthermore, we observed a dependency of the deceleration on the grain boundary type and elastic anisotropy. A 3D-HR-orientation gradient map was gathered by HR-EBSD using the software CrossCourt in combination with a self-provided MATLAB tool to reveal detailed information about strain localization at the grain boundary in the process zone near the crack tip.

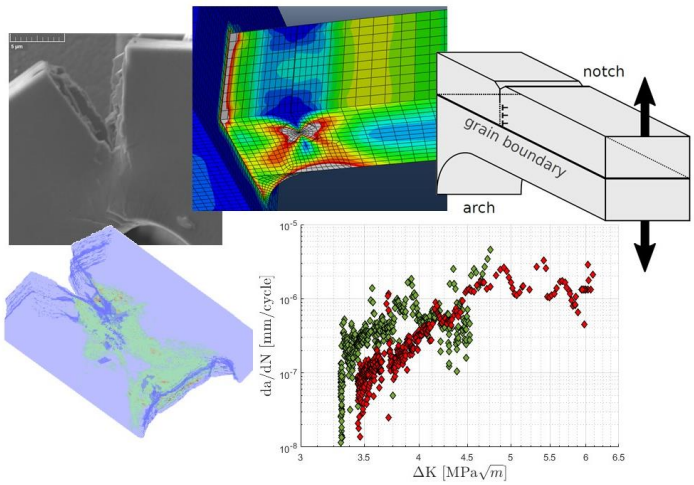

***Figure 1** – Graphical Abstract*

, Non-destructive composites monitoring through the magnetic microwire inclusions

A. Zhukov[1,2,3], A. Allue[4], P. Corte-León[1], K. Gondra[2], M. Ipatov[1,2], J. M. Blanco[2] and V. Zhukova[1,2]

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Real time non-destructive monitoring of stresses and temperature is one of the prospective technologies in the field of smart composites. Thin glass-coated amorphous microwires prepared using the Taylor-Ulitovsky method consisting of metallic nucleus diameters of 0.5-40 μm coated by thin insulating and flexible glass-coating present excellent mechanical softness [1]. Additionally, thin glass-coating provides new functionalities such as improved mechanical and corrosive properties, good adhesion with polymeric matrix and biocompatibility [1]. Recently a novel method for non-destructive monitoring utilizing ferromagnetic microwire inclusions is proposed [2].

In this work we propose a novel sensing technique for non-destructive monitoring of the composites utilizing ferromagnetic glass-coated microwire inclusions with magnetic properties sensitive to stress and temperature. We provide in-situ studies of the evolution of the hysteresis loop of arrays consisting of Co- and Fe-rich microwires, as well as transmission and reflection parameters of the composites with microwire inclusions during the composites matrix polymerization. We observed remarkable change of the hysteresis loops upon matrix polymerization: remarkable coercivity change and transformation of linear hysteresis loop to rectangular or from rectangular to linear for arrays with Co-rich and Fe-rich microwires respectively. Using the free space technique we observed considerable variation of the reflection in the range of 4-7 GHz and transmission upon the matrix polymerization. Observed dependencies are discussed considering variation of temperature and stresses during the thermoset matrix polymerization and their influence on magnetic properties of glass-coated microwires.

References

[1] High Performance Soft Magnetic Materials (editor A. Zhukov), Springer Series in Materials Science, vol 252, Springer International Publishing, 2017, Page numbers: 216p, ISBN: 0933-033X, DOI: 10.1007/978-3-319-49707-5

[2] J. Olivera, M. González, J. V. Fuente, R. Varga, A. Zhukov and J. J. Anaya, Sensors, 14 (2014) 19963.

, **Development of stress-sensitive magnetic microwires for magnetoelastic sensors**

V. Zhukova[1,2], P. Corte-Leon[1,2], M. Ipatov[1,2], J.M. Blanco[2], M. Churyukanova[3] and A. Zhukov[1,2,4]

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[2]*Dpto. de Física Aplicada, EUPDS, UPV/EHU, 20018, San Sebastian, Spain*

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Development of magnetic sensors is focused on the miniaturization of their size, improvement of their features and on finding of new materials. Among new magnetic materials a family of thin wire with reduced dimensions recently gained considerable attention [1]. Glass-coated magnetic microwires prepared using the Taylor-Ulitovsky technique with thin metallic nucleus (typically with diameters 0.5 to 50 μm) covered by flexible, insulating and biocompatible glass are therefore quite interesting for sensor applications. Particularly a few magnetoelastic sensors utilizing stress dependence of magnetic properties of microwires and therefore allowing stress monitoring are proposed [2,3]. We studied the effect of applied tensile stresses on magnetic properties of as-prepared and post processed amorphous $Fe_{75}B_9Si_{12}C_4$ glass-coated microwires. Monotonous increase of coercivity and switching field upon applied stress is observed for as-prepared $Fe_{75}B_9Si_{12}C_4$ microwire. Stress induced magnetic bistability consisting of transformation of hysteresis and onset of rectangular hysteresis loop upon tensile, σ, of about 22.5 MPa is observed in stress-annealed $Fe_{75}B_9Si_{12}C_4$ microwires. Such stress-induced magnetic bistability results in considerable growing of coercivity and remanent magnetization in stress-annealed $Fe_{75}B_9Si_{12}C_4$ microwires. Consequently, stress-annealing of $Fe_{75}B_9Si_{12}C_4$ microwire allows beneficial enhancement of the stress dependence of coercivity. Observed dependencies are discussed considering internal stresses redistribution and domain structure rearrangement in stress-annealed $Fe_{75}B_9Si_{12}C_4$ microwires upon applied tensile stresses.

References

[1] M. Vazquez, H. Chiriac, A. Zhukov, L. Panina and T. Uchiyama, On the state-of-the-art in magnetic microwires and expected trends for scientific and technological studies, Phys. Status Solidi A, 208 (2011) 493-501.

[2] M. Churyukanova, S. Kaloshkin, E. Shuvaeva, A.Stepashkin, M. Zhdanova, A. Aronin, O. Aksenov, P. Arakelov, V. Zhukova, A. Zhukov, "Non-contact method for stress monitoring based on stress dependence of magnetic properties of Fe-based microwires", J. Alloys Compd., 748, 5 (2018) pp. 199-205.

[3] D. Praslička, J. Blažek, M. Šmelko, J.Hudák, A. Čverha, I. Mikita, R.Varga and A. Zhukov, "Possibilities of Measuring Stress and Health Monitoring in Materials Using Contact-Less Sensor Based on Magnetic Microwires", IEEE Trans. Magn., 49(1) (2013) pp. 128-131.

, Analytical model for estimation of energy release rate at mode I crack tip in bi-material of identical steels joined by an over-matched weld interlayer

Sunil Bhat

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Structure fabricated by welding identical steels or a fractured steel component repaired by steel weld filler of different strength leads to the presence of two interfaces with strength mismatch across them, one interface between parent steel and weld and the other between weld and back up steel. Mode I crack in such a bi-material upon growing across the weld interlayer experiences the effect of the interfaces that manifests by way of change in crack tip energy release rate, J_{tip}, from the far field value, $J_{applied}$. The paper presents a strain based analytical model for estimation of $J_{interface}$ and thereby J_{tip} at all the positions of the crack under SSY or K dominant conditions. Results of mode I crack in front of a single strength mismatched interface have been reported earlier. Sequential effect of two interfaces over the crack tip is taken up in the present work. The weld interlayer is assumed to be homogeneous and over-matched which possesses higher strength than that of the constituent steels. The modulus of elasticity is same throughout the domain. Edge crack of various discrete lengths, c, is investigated in infinite body under uniform monotonic tension of 150 MPa in plane stress situation for demonstration of the model behavior. Influence of weld thickness over J_{tip} is also examined.

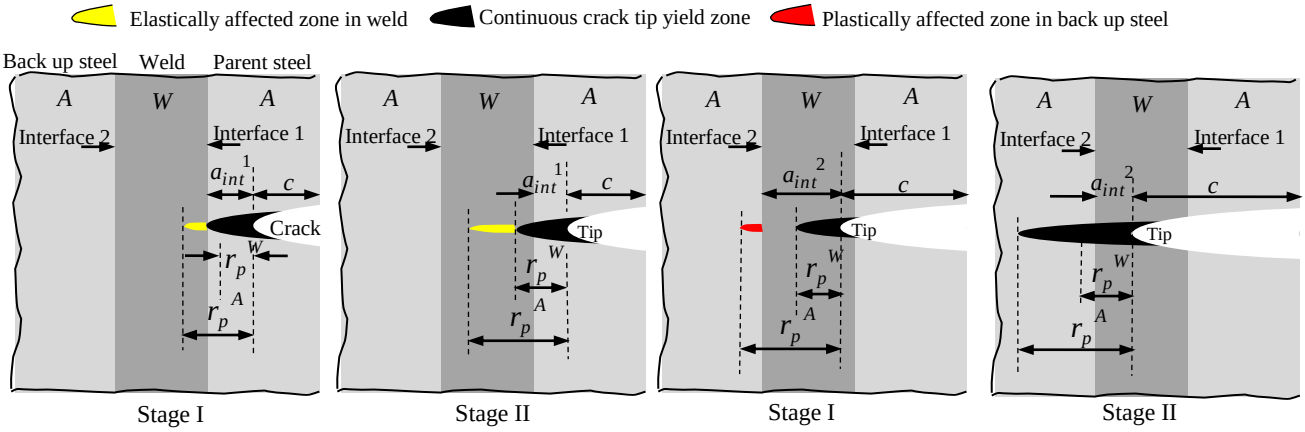

Fig. 1a) Crack tip in front of interface 1 (Weak-Strong transition)

Fig. 1b) Crack tip in front of interface 2 (Strong-Weak transition)

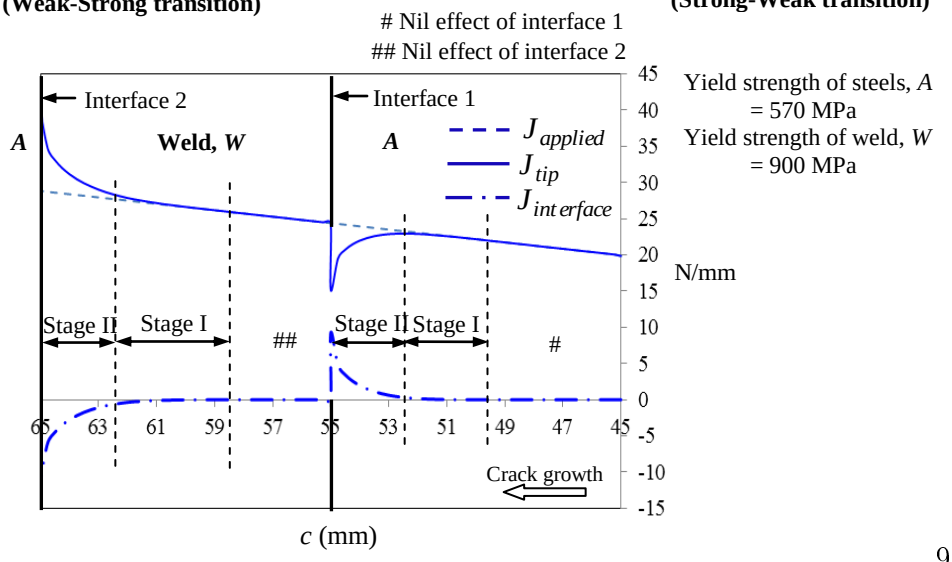

Fig. 2. Energy release rate *vs* crack length (weld thickness = 10 mm)

, A review of present status and challenges of using additive manufacturing technology for offshore wind applications.

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Abstract

Offshore wind is an efficient sustainable source of energy, which is a preferable alternative to burning fossil fuels in the United Kingdom and Europe. About 85% of existing offshore wind turbines have a monopile foundation, which are made of large welded plates. The residual stresses locked in a monopile structure have a great impact on its fatigue life. The new emerged technology of additive manufacturing (AM), which is widely used in other industries such as aerospace and automotive, has potential to significantly improve a lifespan of the structure by managing the residual stress fields and microstructure in the future monopiles, and moreover reduce the manufacturing cost. New materials that are used for additive manufacturing parts fabrication and their behaviour in harsh marine environmental and operational loading conditions needs to be understood. Also purely welding fabrication technique employed during AM process is likely to significantly affect crack growth behaviour in air as well as in seawater. This paper presents a review of additive manufacturing technology and suitable techniques for offshore structures. Existing literature that reports current data on fracture toughness and fatigue crack growth tests conducted on AM parts is summarised and analysed, highlighting different steel grades and applications, with the view to illustrating the requirements for the new optimised functionally graded structures in offshore wind built by means of AM technique.

, Hygrothermal stresses Analysis of Thick Composite Plates Using High Order Theory under a Fick Concentration Distribution

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Abstract The composite materials fields is very important with their wide use in various fields, in aeronautics these materials represent a great potential throught their rigidity and lightness, the aeronautical structures work in variable environmental conditions because of altitude change ,consequently the temperature and the humidity in which the structure is located vary, these parameters generate an internal stresses which influence the behavior of the material, for this the determination of the hygrothermal stress is very important in the engineering phase.

This study investigates the behavior of thick composite laminates using the high order method through hydrothermal stress calculation, the composite laminate is working in a symmetric hygrothermal environment, temperature and humidity are used and taken into account for stress calculation, the moisture distribution is calculated along the thickness of the laminate using the Fick equation, different Simulations are carried out using different values of temperature and concentration, to see the influence of one on the other, other simulations are made by varying the distribution shape of temperature along the thickness of the laminate, the plate size is also taken into account in the simulations (a/b: ratio of length to width, a/h: ratio length to thickness).

Fatigue life of a bus structure in normal operation and in accelerated testing on special tracks

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Abstract Over the last twenty years, the Research and Testing Institute in Pilsen has been developing a methodology of computational and experimental investigation of strength and fatigue life of bodies of road vehicles for mass passenger transport. A summary of this methodology has already been presented, e.g. in (Kepka-Špirk, 2015). The methodology includes multibody dynamic simulations, strength FEM calculations, test bench tests, stress measurements during vehicle prototype operation, evaluation of measured data and fatigue life calculations. One co-operating bus manufacturer plans to include accelerated fatigue tests on a special test polygon into this procedure. In real urban traffic and on the test circuit extensive stress measurements on a number of structural nodes and components has been carried out and analysed. In collaboration with the Regional Technological Institute, which is the research center of the Faculty of Mechanical Engineering of the University of West Bohemia, the fatigue life was calculated for the critical nodes and components of the different parts of the bus. Based on these calculations, it was possible to assess the development potential and problem of planning accelerated tests on the test polygon.

Section	km
slope circuit	3.80
speed circuit	2.80
arrival to special roads	0.07
panel road	0.45
exit/arrival	0.13
sinus resonance road	0.40
exit/arrival	0.15
paved road	0.40
exit/arrival	0.15
paved road	0,40
exit/arrival	0.15
paved road	0.40
exit/arrival	0.16
Belgian paving	0.40
exit from special roads	0.08
speed circuit	1.90
Total	11.84

***Figure** – Composition of the test track on the test plygon.*

Kepka, M., Spirk, S.: Tests and computer simulations of electric buses. Proceedings M2D2015 - 6th International Conference on Mechanics and Materials in Design, Porta Delgada/Azores/Portugal, 26-30 July 2015

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Numerical analysis of time-dependent deformation effects on preload relaxation behavior of offshore wind turbine bolted connections

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Abstract

Offshore wind is a reliable source of clean energy which is becoming a preferred solution for meeting the electricity demand in Europe and worldwide. The majority of operating offshore wind turbines are supported by monopile type foundations which consist of cylindrical welded cans typically made of structural steel plates. In a considerable number of recent generations of offshore wind farms, the monopile foundations are attached to a transition piece using bolted flange connections. One of the major structural integrity issues associated with these connections, is the short-term and long-term preload relaxation in individual bolts and nuts during operation which requires frequent inspections to ensure that a minimum allowable preload level is maintained in each bolt. One of the key mechanisms which can significantly influence the short-term relaxation of offshore wind turbine bolted connections is the time-dependent elongation of the bolt and nut materials under a constant load, which is referred to as room temperature creep deformation. A numerical investigation has been performed in the present study to examine the effects of room temperature creep deformation on short-term preload loss in M72 bolted connections. The results from this study show that although creep is usually neglected at low temperatures, at preload levels close to the yield stress of the bolt material relatively large levels of creep deformation may occur which subsequently reduce the remaining preload in bolted connections. Therefore, recommendations have been made to consider room temperature creep properties in analysis of preload loss in monopile to transition piece bolted flange connections. Finally, a sensitivity analysis has been carried out to investigate the influence of creep properties on the extent of preload loss in M72 bolted connections.

, Finite Element Models Describing the Failure in Steel Cable-Reinforced Rubber Composites

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Abstract Steel-cable reinforced rubber composites are used in a variety of applications such as tires and conveyor belts. Whereas the rubber matrix allows for big deformations of those composites, the steel cables provide stiffness in certain directions. Those cables consist of spiral (twisted) strands, which has two consequences: The ratio between tensile and bending stiffness is much higher than in a solid rod, and they feature a tension/torsion coupling, i.e. when not constrained, a tensile load also causes a twisting deformation. These effects make the failure of such composites very complex, and it is very hard to predict failure loads and locations in certain steel-cable reinforced rubber composite.

To study this complicated failure behaviour, simple test specimens with three cables (see Fig. 1) were used, where failure occurs in the cable/rubber interface and/or as crack propagation in the rubber. This failure is similar to failure modes observed in real realistic steel-cable reinforced rubber components.

For classical composites, the Finite Element Method (FEM) provides a well-established tool for calculating deformations and predicting failure. This work attempts to model the deformations and predict the failure in steel cable-reinforced rubber composites in a similar way. However, modelling of the hyperelastic behaviour of such composites is a big challenge due to the huge stiffness difference of the two constituents since minor deformations of cables such as coupling effects can significantly change the stress state in the rubber. Predicting the failure behaviour of cable-rubber composites is an even bigger challenge, because an accurate description of the composite's deformations and local stress distributions are necessary. A key feature of the developed model is the accurate description of the complex rubber- and cable behaviour. The cable is modelled in a homogenized way, and different methods of introducing the coupling effects are investigated: e.g., the tension/torsion coupling can be mimicked by anisotropic material models.

Being able to accurately capture the failure loads, locations and developments of such simple specimen, the developed method will be able to be applied to realistic structures that contain a large number of cables and a complex geometry.

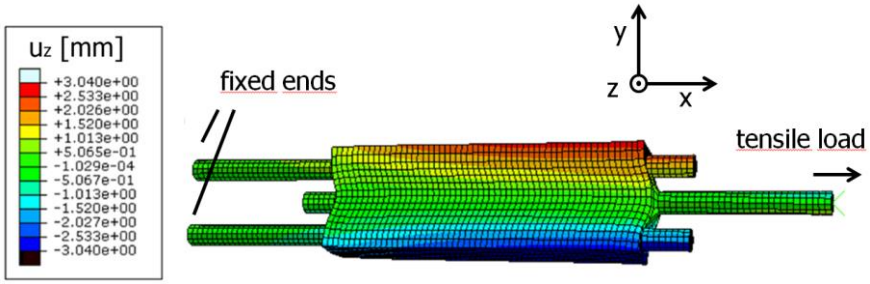

***Figure 1** – Specimen containing three cables: Applied forces are transmitted in the rubber. Note that the contour plot shows the out-of-plane displacements that are caused by the tension-torsion coupling effect in the cables.*

, ENERGY ABSORPTION CAPABILITIES OF PERIODIC CELLULAR MECHANICAL METAMATERIALS FOR IMPROVED CRASHWORTHINESS

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Abstract In this paper, the effect of cellular mechanical metamaterials with hexagonal unit cells and variable wall-thickness were investigated with relation to crashworthiness. An auto-generated algorithm was developed to computationally model the metamaterial shown in Fig. 1c; commence crush simulation; and output crashworthiness parameters – specific energy absorption (SEA), peak crush force (PCF), and crush force efficiency (CFE). These parameters were compared to those of a hexagonal cellular material with uniform wall-thickness (Fig. 1a) and a monolithic material (Fig. 1b). The metamaterial, compared to the cellular material, had higher SEA, CFE, but also high PCF. However, the metamaterial exhibited lower PCF and CFE similar to the monolithic, but the SEA was lower as well. Subsequently, the optimal structure for improved crashworthiness requires low PCF, but high SEA and CFE. Therefore, further studies involving geometrical study and optimisation needs to be carried out.

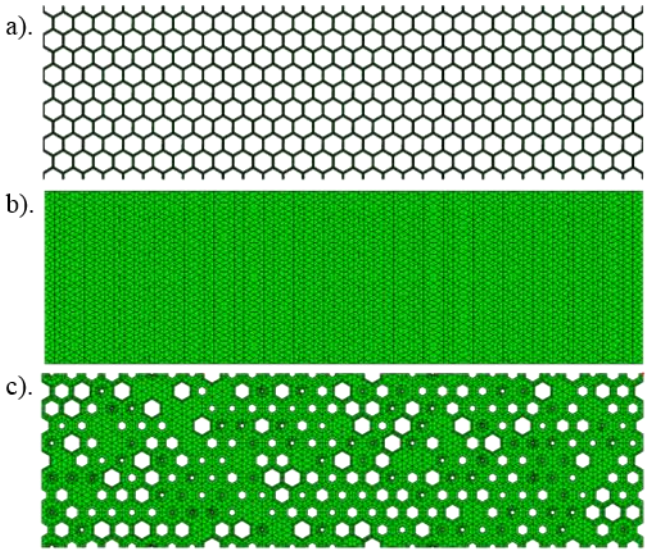

Figure 1 - *Auto-generated computational model of a) cellular material with hexagonal unit cell and constant wall-thickness, b) monolithic material, c) periodic cellular mechanical metamaterial with hexagonal structures, with variable wall-thickness.*

Numerical analysis of auxetic yarns with composite matrix interaction.

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Abstract A modelling method of auxetic yarn (Helical Auxetic Yarn type) cooperating with the composite matrix was presented. The two-component yarn surrounded by a flexible material is a fragment of composite, that consists of an auxetic fabric as a reinforcement and a flexible matrix. Such composite can be used in energy absorbing structures. The HAY as an auxetic material is characterized by a negative Poisson ratio. The stiff fiber spirally wrapped around the elastic core with a larger diameter gives this structure of anomalous behaviour during tensile. Stretching of such yarn increases its dimensions in transverse directions. Helical Auxetic Yarn are sewn into fabric which is durable, flexible and light. The conducted analysis of the fragment of the composite reflecting one yarn allows for pre-adjustment of values of matrix material parameters. The purpose of the modelling is to determine the values of parameters a composite matrix that should have to allow the effective work of auxetic yarn. If the matrix were to stiff it would block the capability of bending the core fiber during stretching and the auxetic phenomenon would be cancelled. The key problem is performing these analyses with appropriate value of the Young's modulus of the composite matrix material to get the optimal composite structure. Finite Element Method analyses were conducted in LS-Dyna solver. Discrete model was build using hexagonal, solids elements. It was assumed that the matrix completely filled the spaces between the fibers, and at the outside it had the shape of the cylinder. The choice of such matrix shape allowed to carry out proper interpretation of the displacement values of nodes located at the boundary plane of the matrix model. The displacement of these nodes determines the proper work of the auxetic yarn. Relevant constitutive material models were used to reflect the work of the aramid wrap as well as the elastomeric core and matrix. Nodal displacement was applied to the one of the end of model to simulate tension under static conditions. FEM analyzes were based on the implicit method, which is well suited for simulation of static processes, where final state is the most interesting. Based on the results of the conducted analyzes, it was possible to choose the appropriate matrix material of the composite without preparation of many composite samples with various elastomer matrix and carrying out many experimental tests.

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Wang Z., Zulifqar A., Hu H., Auxetic composites in aerospace engineering, Chapter December 2016, DOI 10.1016/B978-0-08-100037-3.00007-9

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Residual Stress Management - RSM: An Indispensable Tool in Structural Integrity

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Abstract Residual stresses introduced before, during or after welding and other operations like machining, forging, rolling, surface treatments, casting, heat treatment, etc., may change considerably the engineering properties of materials and structural components by affecting their structural integrity through a decrease in their fatigue life, introduction of distortions, reducing the dimensional stability, decreasing corrosion resistance, etc. They play an exceptionally significant role in fatigue of welded elements.

The concept of residual stress management therefore is becoming an indispensable tool in fully understanding the effects of residual stresses by addressing major aspects of residual stresses in welds, and in welded and assembled structures [1, 2]. According to the concept three major stages, i.e. RS determination, RS analysis and RS redistribution are considered and evaluated, either experimentally or theoretically to achieve the optimum structural integrity and performance.

The sound structural integrity of parts and components benefits directly from the RSM concept at all stages of welding and other processes. This presentation will provide an overview on the advancements made in addressing the development of instrumentation for providing solutions in the major stages of the RSM concept. Examples of industrial applications of the developed engineering tools for residual stress analysis and fatigue life improvement of welded elements and structures are given.

Keywords: Structural integrity, residual stresses, ultrasonic method, non-destructive measurement, underwater ultrasonic peening, UltraMARS®-7, UltraPeen®

1. J. Kleiman, Increasing Fatigue Life in Marine Structures through Effective Residual Stress Management, Shipbuilding Technology Forum, Ottawa, Canada, 1 March, 2018;
2. J. Kleiman and Y. Kudryavtsev, Residual Stress Management in Welding: Residual Stress Measurement and Improvement Treatments, 10th International Conference on Residual Stresses, (ICRS-10), 3-7 July, 2016, Sydney, Australia.

Latest developments in nondestructive testing of residual stresses in welded structures by ultrasonic method

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Abstract Using the well-developed acousto-elastic theory of interaction of acoustic waves with materials and the existing linear relationships between the dependence of acoustic wave propagation in materials on stresses, a portable system for non-destructive measurements of residual stresses, the Yong Modulus, Poisson Ratio and thickness was developed and used successfully in numerous applications [1,2]. The system includes a measurement unit with transducers and basic supporting software. The developed system allows measuring the RS either averaged through thickness or in surface or subsurface layers, with the results displayed on the screen of the instrument as a continuous curve.

The present version of the system allows measuring the averaged through thickness biaxial RS in parts ~ 2 - 150 mm thick as well as the surface/subsurface RS at the predetermined depth from hundreds of microns to a few mm in depth. Additional features of the system allow also measuring the Yong Modulus and Poisson ratio as well as the thickness of material.

A number of changes were introduced recently into the software and measurement protocols of the system and the transducer design. The presentation will include new information on recent updates to the system and will present examples of stress measurements in large scale welded specimens and structures.

Keywords: residual stresses, non-destructive measurements, ultrasonic method, measurement of Young Modulus and Poisson Ratio, bulk, surface, subsurface stresses

Figure 1 – *Ultrasonic complex for non-destructive measurements of residual and applied stresses- UltraMARS-7*

References

1. Y. Kudryavtsev and J. Kleiman, Ultrasonic Measurement of Residual Stresses in Welded Elements and Structures, 19th World Conference on Non-Destructive Testing (WCNDT 2016), June 13-17, 2016, Munich, Germany.
2. J. Kleiman, Non-destructive Measurements of Residual Stresses in Bridges Using an Ultrasonic Method, ASNT Annual Conference, 28-31 October, 2018, Houston, USA

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Numerical analysis of pitting corrosion fatigue in floating offshore wind turbine foundations

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Abstract

The mooring lines of offshore floating wind foundations, which anchor the floating foundations to the seabed, sustain large dynamic loads during operation. The mooring chains are welded to the floating foundation below the water level. The corrosive marine environment and the cyclic loading make the mooring point susceptible to corrosion pitting and fatigue crack initiation and propagation from the pits, particularly in the weld zones. In this study, a finite element analysis of the crack initiation and growth from corrosion pits has been performed and the results are presented in order to provide an estimate of the extent of damage during the structure's life span. A Python code has been developed as a part of this study which is based on a non-uniform random distribution model which generates arbitrary pits with different depths and aspect ratios. The range of pit size variation has been chosen based on the experimental data available in the literature. The pits are modelled as elliptical cracks and are embedded in a 3D mooring connection area with the floating foundation using ABAQUS XFEM simulations. The Walker's model has been applied in the model to examine the effect of realistic R ratios acting in floating structures on pitting corrosion fatigue crack propagation. The numerical results obtained from this study are discussed in terms of the corrosion pitting effects on fatigue crack initiation and propagation behavior in Spar-type floating offshore wind turbine foundations and the remaining life estimation for these offshore fleets.

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Material Mechanics of Crack Growth in Structural Dynamics

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Abstract This review paper presents the latest research focusing on the crack propagation of the structures under complicated dynamic loads. The reviewed publications involve the variable methodologies to study the fracture mechanics of structures under the fatigue stress regime. Besides, the paper discusses the fatigue crack growth under different loads. The paper presents the research about the thermo-mechanical fatigue and fracture of the structure with metal, composite and polymer materials. In the end, the potential challenges and the current research gaps are summarised.

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, Evaluation of damage in concrete from structures affected by internal swelling reactions – A case study

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Abstract Currently, a significant number of concrete infrastructures (e.g. dams and bridges), in Portugal and throughout the world, are affected by internal swelling reactions (ISR). Among the various reactions that can cause concrete swelling, the most common in Portugal are the alkali-silica reaction (ASR) and the internal sulfate reaction (DEF). From the 60 large concrete dams that are currently being monitored in Portugal, there are 19 dams in which the concrete swelling phenomena has already been identified. It is expected that the number of ISR affected bridges will soon surpass that of dams. In Portugal, a dam was demolished and replaced by a new one in 2014 due to ASR induced expansion and distress, a bridge was decommissioned and replaced by a new one in 2015 due to deleterious development of both ASR and DEF, and several bridges had to suffer expensive rehabilitation works the keep them operational. Moreover, there are still new structures being built that will ultimately suffer from ISR deterioration either because existing guidance was not followed or simply due to limitations of available recommendations. As such, ISR-affected structures will continue to wave our infrastructure for years to come.

Existing knowledge on ISR does not allow for a complete assessment of the actual condition of an affected structure and an accurate prediction of the mechanical properties deterioration and, consequently, of the period during which the structure will effectively perform its function, essential for the timely and cost-effective planning of the necessary mitigation, rehabilitation or reconstruction works. Therefore, to help surpassing this situation, a research project is being conducted at LNEC to contribute to the establishment of a method for the accurate determination of the current level of ISR progression and of the deterioration of the concrete mechanical properties. These are essential to the adequate overall appraisal of an affected structure, and the development of structural models that predict risks to structural integrity, potential for further deterioration due to other mechanisms, need for mitigation or remediation actions, and the remaining service life of the affected structure.

This paper aims to contribute to the ongoing discussion of this topic by the scientific community and, therefore, presents the methodology followed to assess the condition of the concrete from an ISR-affected motorway underpass in Portugal. It includes an extensive experimental campaign, performed to concrete cores extracted from the structure, comprising the latest advances in the field, to allow for an adequate diagnosis and prognosis of the expansive reactions development in the concrete. The results obtained in the study evidenced the utility of such a methodology on the appraisal of the actual expansion level attained to date in the concrete from ISR-affected structures.

, Durability of Hypotrochoidal Polygon-Shaft-Hub Connections under Rotating Bending with Static Torsion

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Abstract Shaft-hub connections primarily function is the transmitting of torsional moments. The polygon-shaft-hub connection is a type of shaft-hub connection with increasing importance. Compared to conventional press fits, a main advantage of this type of connection is the additional normal force in the contact joint due to the eccentricity of the polygonal profile. This results in the possibility of transmitting high static torsional moments. These static torsional moments are often occur with rotating bending loads in real applications. Due to that aspect this combined load case is of particular importance for shaft-hub connections. Therefore, the currently unknown high cycle fatigue strength of polygon-shaft-hub connections is experimentally investigated in this paper.

Part of the investigations are hypotrochoidal polygon-shaft-hub connections with three and seven carriers (cf. Figure 1, left). Shaft and hub of the connection are manufactured from steel 1045 and have an interference fit of 0.5 ‰. The fatigue strength tests consist of test blocks with rotating bending and rotating bending with static torsion (cf. Figure 1, right). The test procedure is based on the modified stair case method. Notch factors are calculated from the fatigue strength values, the equivalent resistance moments of the cross-sections and the determined material properties. Based on the notch factors we develop a calculation method for the fatigue strength of hypotrochoidal polygon-shaft-hub connections integrated in a nominal stress concept.

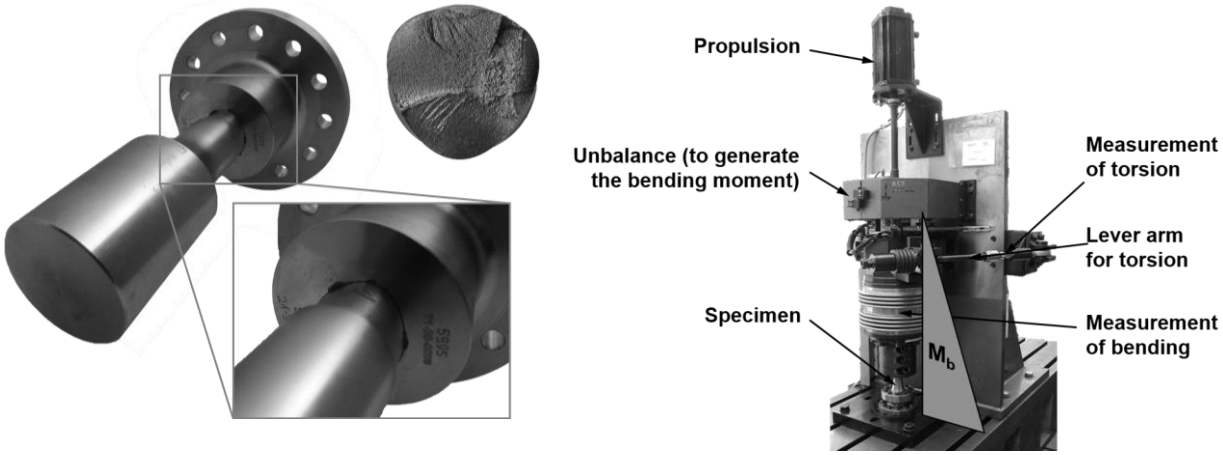

***Figure 1** – left: hypotrochoidal polygon-shaft-hub connection with fretting corrosion and fracture pattern; right: test bench for bending with static torsion*

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Monitoring mass changes using nanoresonator sensors

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Abstract. Nanobeams are frequently used as vibration based-sensors to detect small adherent masses caused, for instance, by the addition of foreign atoms/molecules or by chemical/molecular absorption. The mass sensing principle is based on the use of the resonant frequency shifts caused by unknown masses attached on the surface of a referential nanobeam. In spite of its importance in applications, few studies are available on this inverse eigenvalue problem. In this paper, we have developed a reconstruction method of a distributed mass on an initially uniform nanobeam (modeled with the strain gradient elasticity theory, to take into account the size effects) which uses the first N natural frequencies of the free bending vibration under supported end conditions. The method is based on an iterative procedure that produces an approximation of the unknown mass density by means of a generalized Fourier partial sum of order N, whose coefficients are calculated from the first N eigenvalues shifts. To avoid trivial non-uniqueness due to the symmetry of the initial configuration of the nanobeam, it is assumed that the mass variation has support contained in half of the axis interval. Moreover, the mass variation is supposed to be small with respect to the total mass of the initial nanobeam. An extended series of numerical examples shows that the method is efficient and gives excellent results with N less than 10 in case of smooth (e.g., at least continuous) mass variations. The determination of discontinuous coefficients exhibits no negligible oscillations near the discontinuity points, and requires more spectral data to obtain an accurate reconstruction, typically N=15-20. Some results for mass variation supported on the left half of the nanobeam are shown in Figure 1. Surprisingly enough, in spite of its local character, the identification method performs well even for not necessarily small mass changes. To the authors' knowledge, this is the first quantitative study on the identification of distributed mass attached on nanobeams in bending vibration modelled within generalized continuum mechanics theories by using finite eigenvalue data. The extension of the method to the identification of general added mass distribution (e.g., not necessarily supported on half of the axis interval) is currently under investigation.

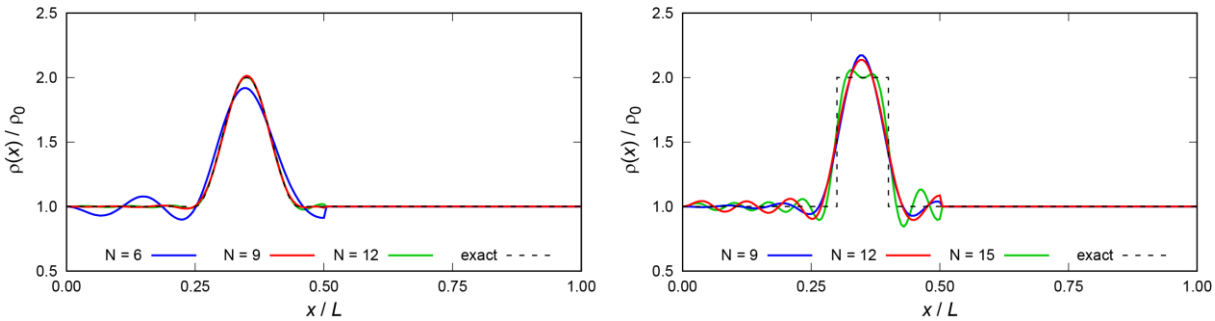

Figure 1. *Examples of reconstruction of smooth (left) and discontinuous (right) mass changes. The function $\rho(x)/\rho_0$ is the ratio between identified and referential mass density per unit length, $0<x<L$, where L is the nanobeam length.*

, Correlation between fractographics aspects and stress intensity factor in very high cycle fatigue

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Abstract Very high cycle fatigue (VHCF) tests carried out at high frequency make it possible to evaluate the behavior of materials, particularly steels, for fatigue lives exceeding 10^6 - 10^7 cycles in relatively short time intervals compared to conventional fatigue tests. This reduction in the test duration is due to the ultrasonic frequencies, usually situated in the range 15 - 30 kHz, provided by the test machines. In the VHCF regime, the fatigue crack tends to start internally or in subsurface from internal defects, intrinsic to the material. The evolution of fatigue cracks occurs in different stages: crack initiation, crack growth within the fish-eye, crack growth outside the fish-eye, and then final fracture. In addition, another phenomenon that may occur inside the fish-eye and nearby the initial defect, is known as fine granular area (FGA). VHCF tests of a crankshaft steel were performed at a frequency of 20 kHz and loading ratio of -1. The S-N curve shown below indicates an increase in fatigue life as the applied stress decreases. The fracture surfaces analyzed have also indicated the presence of fish-eye which includes an FGA region. Aspects referring to fish-eye and FGA are presented and related to stress intensity factor (SIF) and number of cycles to failure.

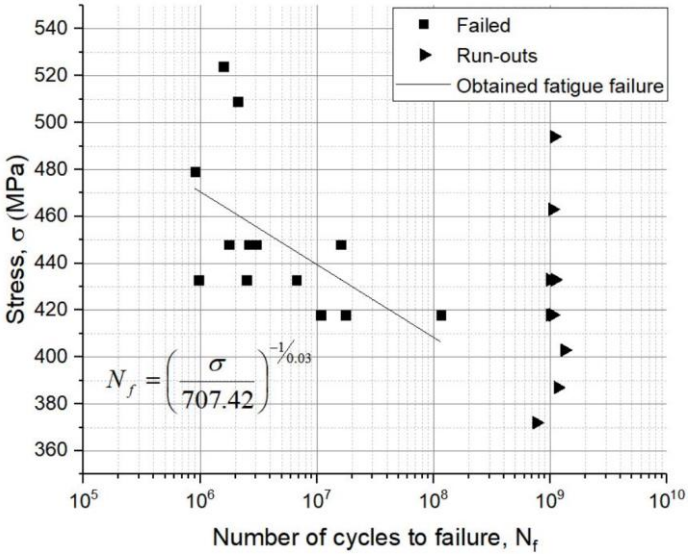

Figure 1 – *VHCF S-N curve for a crankshaft steel.*

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Landing Gear Structural Health Monitoring (SHM)

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Abstract This paper provides information on the development of a landing gear Structural Health Monitoring (SHM) system that provides prognostic/diagnostic HUMS capabilities through direct load measurement in addition to strut servicing detection algorithms. The system provides advanced monitoring technology via the incorporation of new sensors integrated into the landing gear assembly. The direct load measurement approach is a paradigm shift from current methods of tracking fatigue damage of airframe landing gear systems and fuselage support structures, which depend on data collection of aircraft parameters recorded onboard at various sampling rates by SHM devices. The landing gear SHM provides direct loads measurement, weight/balance calculations, and the ability to perform Condition Based Maintenance (CBM) on the landing gear components.

NAVAIR has currently contracted with ES3 to support the development of the landing gear SHM via the Small Business Innovative Research (SBIR) program, via a Phase II award on the N121-043 topic. The proposed solution will be directly transferable to other Navy, military and commercial aircraft platforms. This paper will address the following topics in the area of HUMS and CBM: (1) advanced landing gear sensors for direct load measurement; (2) data fusion of direct loads monitoring data into fatigue life assessments; (3) paradigm shifts in aircraft maintenance utilizing strut servicing detection algorithms; (4) system verification and validation; and (5) safety and maintenance benefits.

Prior work in the field of spectrum development and usage monitoring has typically focused on the aircraft structure, with assumptions translated to the landing gear components without any direct measurement. The benefits of usage monitoring can also be realized for landing gear. Direct loads measurement provides the ability to extend service life, remove components based on actual loading, improve safety, increase aircraft availability, and save maintenance costs with incorporation of CBM data into the maintenance practices. This paper advances the state-of-the-art via the miniaturization of sensors rated for the severe landing gear environment at a high Technological Readiness Level (TRL).

The technological readiness of the landing gear SHM sensors has advanced, with several SHM sensors currently flying on aircraft for loads spectrum data collection purposes. This paper varies from prior publications, in that the prior applications concentrated on fluid level detection for CBM purposes—while this paper enhances the SHM system capability via the addition of direct load monitoring devices throughout the landing gear structural load path.

, Analysis of the structural girders of a crane for the license renewal of a BWR nuclear power plant

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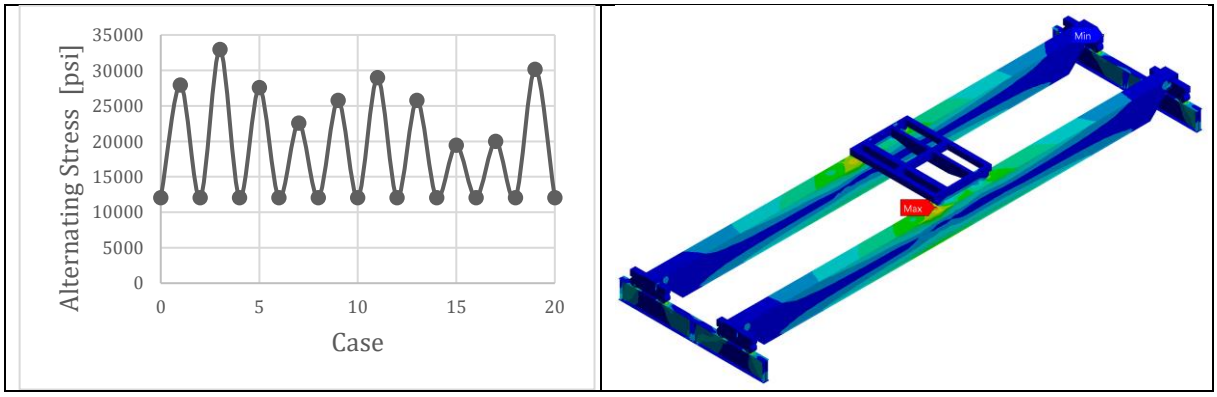
Abstract This work presents a Time-Limited Aging Analysis (TLAA). The objective was to determine the Cumulative Usage Factor (CUF) of the structural girders of an overhead traveling bridge crane. This crane is located inside the reactor building of a nuclear power plant type BWR. This analysis is important to comply with the requirements for the renewal of an operating license of a nuclear power plant.

The Finite Element Method (FEM) is applied with the ANSYS code. Analyzes were carried out three-dimensional. Alternating stresses were determined at the critical points and the Miner rule was used to estimate the Cumulative Usage Factor (CUF) projected at 60 years.

The results shown two critical cases (Figure 1, case 3 and 19). These are the test of the crane before each operation and the handling of spent fuel containers. A Cumulative Usage Factor (CUF) of 0.000259 projected at 60 years was calculated. This complies with the 10 CFR 54.21 (c) (1) (ii) standard. It shows that the CUF remains less than one. This ensures that the integrity of the structural girders is maintained during an extended period of the operating license.



, ***Figure 1 –*** *Alternating Stress in the structural girders under different transient*

, Numerical analysis of the BWR-5 beltline region containing a crack postulated for an extended period of operation.

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Abstract. The initial operation licence of a nuclear power plant is granted for forty years. However, currently, the owners are applying to operate an additional extended period of twenty years. Other situation which can take place during the life time of a nuclear power plant is its uprate of the output power. In both cases, the reactor vessel wall is exposed to additional neutron radiation that induces embrittlement. Besides, thermal transient conditions must be incorporated in the analysis. For this reason, it is important to evaluate the structural integrity of the reactor vessel and manage its aging.

In the case of a BWR-5, the material of the wall at the location named “beltline” is subjected to embrittlement, lowering the fracture toughness and increasing the yield strength. The welds located at this area are weak points so flaws or cracks can be developed. The structural integrity of the beltline region has to be evaluated following a Fracture Mechanics approach. In this paper, it was postulated a crack through thickness in the axial direction. The maximum dimensions that can be allowed were considered. Specifically, its depth was 0.25 of the thickness of the vessel and its length was one and a half of such thickness. The material of the vessel is SA-533 low alloy carbon steel.

Initially, the structural integrity is evaluated for forty years of operation. To consider an extended operation, the analysis must be extended to cover sixty years of operation. The normal conditions of operation and start-up and shutdown transient were taken into account in the evaluations.

For this purpose, a numerical evaluation is performed with the Finite Element Method to evaluate a linear elastic fracture mechanics analysis. This analysis is done under the regulations of the Appendix G of the ASME Code Section XI and the NUREG-0800. Finally, the stress intensity factor K_I was obtained and it is compared with K_{IC} of the irradiated material, so parameters of operation (pressure and temperature) are provided.

, Degradation of microstructure and properties of an AISI 316L steel tube after more than 100,000 hours usage at 640°C in a petrochemical industry

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Abstract AISI 316L austenitic stainless steel is one of the most widely used in its steel class, especially at high temperature. In this work, samples for analysis were taken from a tube of AISI 316L with a nominal 203 mm external diameter and 15 mm thick exposed for about 100,700 hours at 640°C with internal pressure of 4.5 MPa in a reactor of a petrochemical plant. Modifications in microstructure, mechanical properties and corrosion resistance were investigated and the most important results are presented. Results show the precipitation of intermetallic phases, mainly sigma phase at grain boundaries and inside the grains. Precipitation caused increased hardness, yield strength and ultimate tensile strength and decreased ductility, toughness and intergranular corrosion resistance.

Keywords: Degradation; AISI 316L; Microstructure; Mechanical properties; Corrosion.

, Notch fatigue behavior of Inconel 718 produced by selective laser melting

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Abstract Selective laser melting (SLM) is an additive manufacturing technology that uses 3D CAD part data as a digital source and fabricates it from a metal powder without the need for part-specific tooling. SLM systems currently produce near fully-dense parts with limited presence of internal defects. Inconel 718 is a nickel–chromium alloy extensively used in gas turbines, rocket motors, space crafts, etc. that is now successfully processed by SLM. The layer-wise fabrication generates directional microstructure and a rather rough surface. The static mechanical properties of SLM Inconel 718 are comparable if not better of their conventionally manufactured counterparts. On the other hand, in the presence of fatigue loading, the as-built surfaces of SLM Inconel 718 parts are a source of weakness. In topologically optimized SLM parts, the effect is further enhanced by many local stress concentrations at geometrical notches and cross-sectional variations.

Information on the notch fatigue behavior of as-built SLM IN718 is still limited. This contribution reports on a study of the link between surface quality, directional material fabrication and the resulting notch fatigue behavior of SLM Inconel 718. An innovative fatigue test method using miniature notched specimens tested in cyclic plane bending is adopted. Four sets for specimens each with a different orientation of the notch surface with respect to the build axis are produced out of Inconel 718 powder by SLM processing (SLM Solutions Germany). The fatigue testing of the as-built specimens shows the directional nature of the notch fatigue response. A metallographic investigation demonstrates the link between surface quality of the notched specimens and the layer-wise fabrication of SLM process. The technological origin of the notch fatigue response is thus clarified.

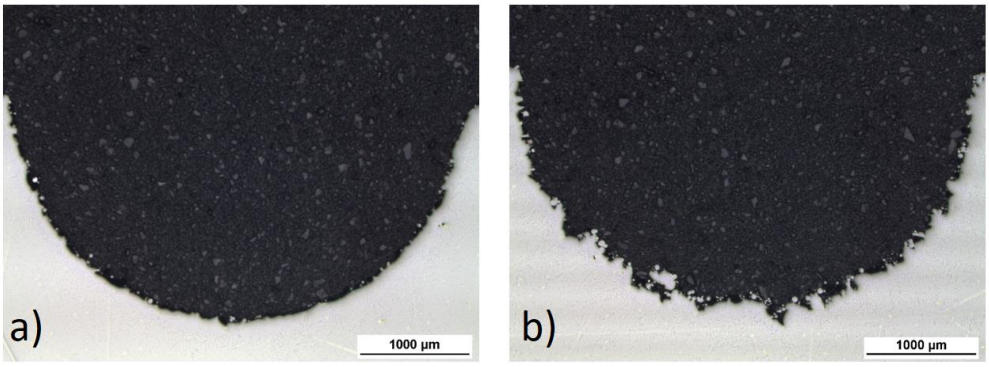

Figure 1 – *SLM fabrication of a semicircular notch (R=2mm)*

a) best quality and b) worst quality

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Microscopic Damage Size in Fiber-Reinforced Polymer-Matrix Composites: Quantification Approach via NDT Measurements

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Abstract The meso-scale morphology of fiber-reinforced polymer-matrix (FRP) composites with fiber plies induces a range of microscopic damage mechanisms when FRP is subject to mechanical or thermo-mechanical loading. Both, for improving the damage resistance of FRP composites and for structural design guidelines, understanding the different damage mechanisms and their interaction is important. Acoustic Emission (AE) monitoring of load tests on laboratory-scale FRP specimens yields information on the occurrence of damage as a function of stress level, and typically allows for roughly locating signal sources, and with sophisticated pattern recognition, for identification of different micro- or mesoscopic damage mechanisms. In FRP components and elements empirical criteria for assessing structural integrity, e.g., AE Felicity-ratio, yield quantitative service-life predictions. Combining AE information on microscopic damage with macroscopic, empirical criteria has not received much attention yet (see, e.g., [Potstada et al. 2018, Figure 1]). Identifying whether stress-relaxation or friction of existing crack faces induces the onset of AE signals in FRP and thus defines the Felicity-ratio is important for structural integrity characterization. This approach to the Felicity effect on the microscopic scale and its advantages and limitations are presented and discussed.

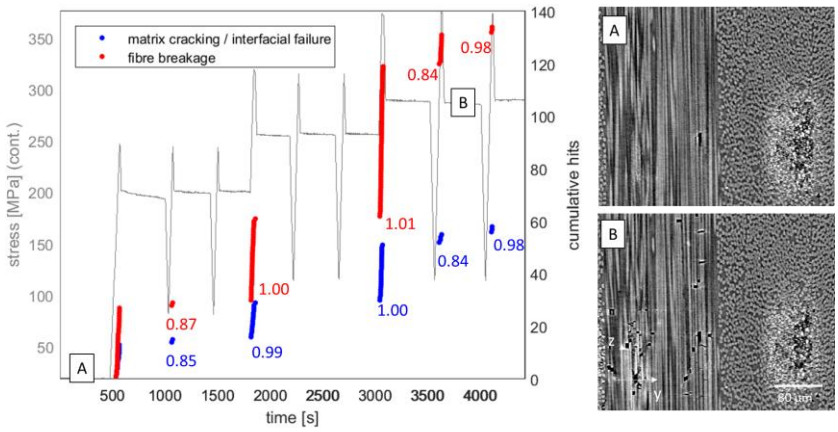

Figure 1 - *Example of layup [±45 0 ±45] including Felicity Ratios evaluated for fibre breakage signals (red) and matrix cracking / interfacial failure related signals (blue) in combination with selected cross-sections from high-resolution in-situ synchrotron computed tomography revealing damage state at load A and B marked in the graph.*

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REVIEW OF ELASTOMERIC MATERIALS FOR APPLICATION TO COMPOSITES REINFORCED BY AUXETICS FABRICS

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Abstract The auxetic composites are characterized by a negative Poisson value. This parameter determines the amount of lateral expansibility referred to the amount of axial compression. Such composites can be made of conventional materials with a positive value of Poisson ratio, but the specific arrangement of the composite reinforcement structures provides this composition with a negative Poisson ratio. It is also possible to create such structures from already existing auxetic subassemblies. In comparison to conventional composites, the auxetic reinforced ones have a lot of positive features, i.e.: higher shear resistance, better crack resistance and better damping properties. The aim of this article is to present the elastomeric materials review for the possible application as the matrix for composite reinforced by auxetic fabrics, especially for fabrics made of Helical Auxetic Yarn (HAY). The essence of creating functional auxetic composites is the selection of a suitable matrix material. It determines the correct work of the HAY. The examples of the usage of various composite matrixes to overview the problem of correct selection of the matrix parameters for the fabrics reinforcement composite were presented in the paper. This matrix is usually made of elastomer or resin with a relatively low hardness to allow proper work of auxetic woven [1]. The interaction of layers of auxetic fabrics with the composite matrix, which positions the HAY woven and transfers the stresses resulting from the work of the auxetics filaments can be found in other authors, research [2]. The elastomeric matrix of the composite should have such elastic and, at the same time, durable properties Long polymer chains contained in elastomer ensure reaching several hundred percent strain during stretching. For this purpose, elastomers based on isocyanates and polyols are used. The review of knowledge presented in this article concerns the issue of interaction of the composite matrix with reinforcement auxetic fabrics and the rule to be followed during the selection of the matrix material.

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Different Failure Mechanisms in Keyed Shaft-Hub Connections under Dynamic Torque Load

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Abstract
Regarding to the possibility of assembling and disassembling as well as its cost-effective manufacturing keyed shaft-hub connections are a very popular way to transmit torque via form fit in modern drive technology. Keyed shaft-hub connections seem to be well known and ordinary in design, although multiple field failures show existing gaps in the design.

Keyed shaft-hub connections can be designed due to two criterions: On the one hand is the maximum permissible contact pressure in the keyways which can cause a failure via an unacceptable plastic deformation of the keyway. On the other hand is the fatigue strength of the shaft. The presentation will be based on a large amount of experimental results of keyed shaft-hub connections under dynamic torque load. The applied servo hydraulic test bench with a schematic sketch of specimen geometry and boundary conditions can be seen in figure 1 left. Main focus will be on the different failure mechanisms and their dependencies. Furthermore the transition from an unacceptable plastic keyway deformation to the initiation of different cracks will be shown.

The experimental results will show that the decisive design criterion for keyed shaft-hub connections is dependent from the shafts material strength (figure 1 right). Keyed shaft-hub connections with shafts made of low strength steel will fail via maximum permissible pressure in the keyway, thus consequently via an unacceptable plastic deformation of the keyway. Keyed shaft-hub connections with shafts made of higher strength steel will be fail through a crack at the shaft without relevant plastic deformation of the keyway. Both design criterions can be handled with different internationally recognized German standards (DIN 743 and DIN 6892). The experimental results will show additionally that both standards have their miscellaneous shortcomings and the presentation will point out potential improvements.

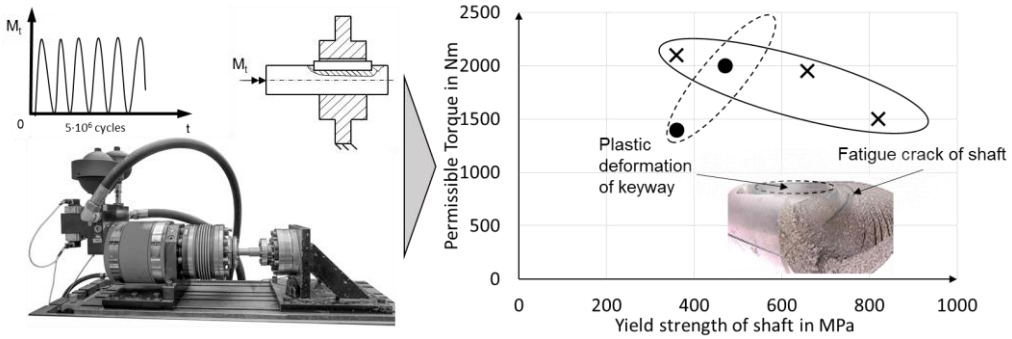

***Figure 1** – left: servo hydraulic torque test bench with schematic sketch of specimen geometry and dynamic torsional load; right: different failure mechanisms in keyed shaft-hub connections depending on shaft's yield strength*

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Reinforcement of building plaster by waste plastic and glass

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Abstract

Plaster is a building material widely used in finishing buildings work, known for its qualities, which allow it a growing demand in the construction market, it is a favorable material to protection of the environment, very malleable, low density, also its thermal and sound insulation, regulator of the hygrometry of the enclosures, decorative, but the fragility of plaster poses a problem in design of decorative pieces with a langue size dimension, which causes problems for the users, in this study the plaster will be reinforced by fiber from waste plastic and powder glass, by introducing ratio (1 and 2 % for plastic fiber and 5 and 10 % of glass powder) additions in to volume of reference specimens plaster studied. The results showed the positive effect of the introducing the waste plastic fiber and glass, that the results show increasing the values of stress in flexion testing, and also the change of ment Allows to evaluate the effect of the addition of the fiber on the flexural strengths and to enhance the plastic waste, the results confirm the advantage of adding the fiber by an improvement in the flexural stress as well as The change in the behavior of the reinforced plaster, on the other hand our work also proposes an addition of glass waste in the form of powder from 5 to 10 % of the mass of the binder (plaster Re).The results show an improvement in the compressive strength of the elaborated specimens.

Keywords: Construction Plaster, plastic fiber, glasses powder, stresses of rupture.

,Effect of pre-strain on cyclic plastic behaviour of 7050-T6 aluminium alloy

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Abstract High-strength 7xxx series aluminium alloys are widely used in the aerospace industry due to their excellent strength-to-weight ratio, high stress-corrosion cracking resistance, good fracture toughness, and low cost. These superior mechanical properties make them ideal for applications which experience repeated loading histories as a result of complex operational conditions and adverse environmental actions. Despite their large use in aircraft structural parts, and the plenty of literature data available about their mechanical properties, the effect of a pre-strain on fatigue life has not been deeply investigated. Nevertheless, the manufacturing cycle or assembly process of the parts may induce stresses whose effects on mechanical behaviour are usually not considered in design. This paper aims at studying, in a systematic manner, the effect of pre-strain on low-cycle fatigue behaviour of 7050-T6 aluminium alloy. Different series of tests under fully-reversed strain-controlled tests for various strain amplitudes and various pre-strain levels are performed. After the tests, the fracture surfaces are examined by scanning electron microscopy to identify the main damage micro-mechanisms. The results show that the higher the pre-strain level, the lower is the fatigue life. This effect tends to increase for higher strain amplitudes.

DCPD based detection of the transition from short to long crack propagation in fatigue experiments on the aluminum alloy 7475 T761

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Abstract

The cyclic lifetime of components can be divided into four sections: crack initiation, short crack growth, long crack growth and critical crack growth. Short crack growth and long crack growth are of particular importance for the engineer. Long crack growth is already well understood, but accounts for only 10 – 30 % of the total lifetime. Short cracks, on the other hand, cover more than half of the service life and are therefore the focus of this study.

During fatigue experiments on single-edge-notched specimens (SEN) of AA7475 T761, cracks were formed in both edges of the notch root, as proven in previous investigations. These cracks are often initiated in different distances parallel to the notch root. In the beginning, they propagate almost independently of each other until they coalesce and form a so-called step. The position of the initiated cracks influences the step, which can vary in form, position, height and length, depending on the microstructure of the specimen and the applied load. The cyclic lifetime correlates with the length of the step. The transition from short crack to long crack growth is defined as the forming of a through-the-thickness crack, which is identical to the point of coalescence and the end of the step. The varying length of the step can be assumed to be the origin of the scatter of the cyclic lifetimes.

With a DC potential drop method, the crack length can be recorded time synchronously during the fatigue test. For the experiments, three high-resolution potential drop probes, attached to different positions near the notch, were used. By comparing the signals, information about the location of the initial cracks and the point of coalescence are obtained. To verify the method, single overloads were introduced to mark the crack position at defined cycle numbers.

The results show, that the use of multiple potential probes improves the detection of initial cracks and gives information about the position of the initial cracks in the notch root.

, An improved technique for high speed impact simulation verification

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Abstract The risk of foreign object impact that can decrease local strength property must be taken into account in the design of primary airframe structures in aviation, energy and space industries. Due to the high-speed impact in operation it can affect the load carrying capacity. Testing all impact scenarios onto real structure is expensive and impractical. The paper is integrate numerical analyses with high-speed impact tests of hail stone on flat panels from metal and composite material. The standard qualitative technique for high speed imact analysis such as high speed camera and post test non descructive technique (NDT) were used for analysis of test results and verification of numerical model (figure 1 – left). New technique of displacement measurement by laser triangulation displacement sensor during impact was proposed and used for quantitative analysis and more precision verification of numerical model (figure 1- right). The ABAQUS FE software was used for high speed impact test simulation. The Smoothed Particle Hydrodynamics (SPH) technique was selected for the simulation of projectiles. The most commonly used shape of projectiles in hail impact tests is the ice ball with a defined diameter. The proposed simulation technique was verified and validated by qualitative and quantitative test results such us the new technigue of displacement measurement during the impact. The influence of plasticity for metal material and damping for composite material is also discussed in regard of displacement measurement and simulation during the imapact. The results form tests and numerical simulation also provide important generalizations for the application and optimization of metal and composite structures.

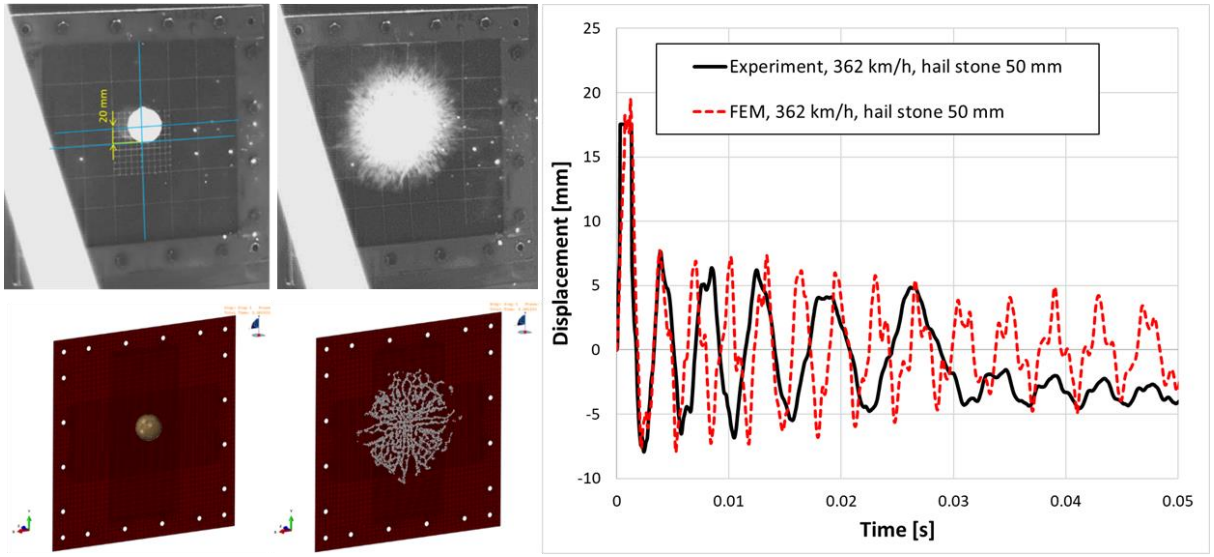

Figure 1 – *Comparison between hail strike test (high speed camera – left, optical sensor measurement – right) and simulation (projectile disintegration – left, displacement in center of test specimen model- right) on composite flat test specimen*

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Load Sequence Effects on the Fatigue and Structural Durablity of Components under Service Load-Time Functions

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Abstract The failure of components under service loading is caused by localized fatigue phenomena, which are governed by the local stress-strain response of the material to an external cyclic loading. Due to stress concentrations at notch-like features, such as, for example bearing shoulders, grooves or any other abrupt changes in the cross-section of the component, also macroscopically elastic external loading may induce a localized plastic deformation of the material. In order to be able to consider elastic as well as elasto-plastic loading during the numerical evaluation of the structural durability, strain-based fatigue design approaches with elasto-plastic material behaviour are the method of choice. As the precision of the numerical fatigue life assessment with strain-based approaches depends mainly on the accurate estimation of the stress-strain state, the consideration of the specific material behaviour and load sequence effects is crucial for the result of the fatigue life estimation and the experimental validation.

The local cyclic elasto-plastic stress-strain state substantially depends on the stress-strain behaviour, the component geometry and the external load-time function. In order to transfer the stress-strain behaviour as well as the fatigue behaviour from the specimen to the component geometry, different influencing factors related to the component size and the localized plasticity have to be considered. Accounting for size and notch support effects, which affect the local stress-strain state as well as the resulting fatigue life, requires finite element analyses on basis of the cyclic stress-strain behaviour, the component geometry and the load assumption. Under variable amplitude loading, especially the load sequence of purely elastic and elasto-plastic loading and transient effects in the stress-strain behaviour influence the evolution of the local stress-strain state and the accumulated damage. The majority of fatigue design guidelines and standards suggest the treatment of load-sequence effects with general safety factors, which are either applied as magnification factors on the load spectrum or as reduction factor on the S-N curve being used for the damage accumulation. As the load spectrum, commonly derived by rainflow counting of the load-time function, does not contain any information about the load sequence, this practice leads to unquantifiable uncertainties which may result either in oversizing or a critical reduction in safety margins.

Considering the influence of the load sequence with physically sound models generally requires a time consuming, piecewise calculation of the elasto-plastic stress-strain state for each load step. The presented work will demonstrate, how a severe reduction in calculation effort may be achieved with a simplified approach for the evaluation of the local stress-strain state under variable amplitude loading. On basis of a static finite element simulation, loads, which cause a shift in mean stresses and mean strains, are extracted from the load-time function, storing also their position in the original load-time function. With elasto-plastic finite element analysis, the shift in mean stresses due to the load sequence is calculated and added to the original load-time function afterwards. A subsequent linear-damage accumulation with the modified load-time function in order to conclude the fatigue life estimation shows a good accordance with the results from the experimental investigations under service loading.

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Description of mixed mode fatigue (I+II, I+III) crack growth in constructional S355/P355NL1 steels using J-integral approach

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Abstract In this paper, the problem of fatigue crack growth description under mixed mode loading condition is considered. A new ΔS^* crack driving force is proposed for mixed-mode loading conditions based on strain energy density parameters. Mixed mode (I+II) fatigue crack growth rate experiment performed for R=0.05 and R=0.5 (P355NL1) confirmed the usefulness of ΔS^* parameter as a crack driving force. For mixed mode (I+III) experiment for R=0, -0.5, -1 (S355) similar invariance of the kinetics fatigue fracture diagrams were observed. On the contrary to the force approach based on ΔK, the energy approach allows describing the kinetics of fatigue crack growth independently from stress ratio R.

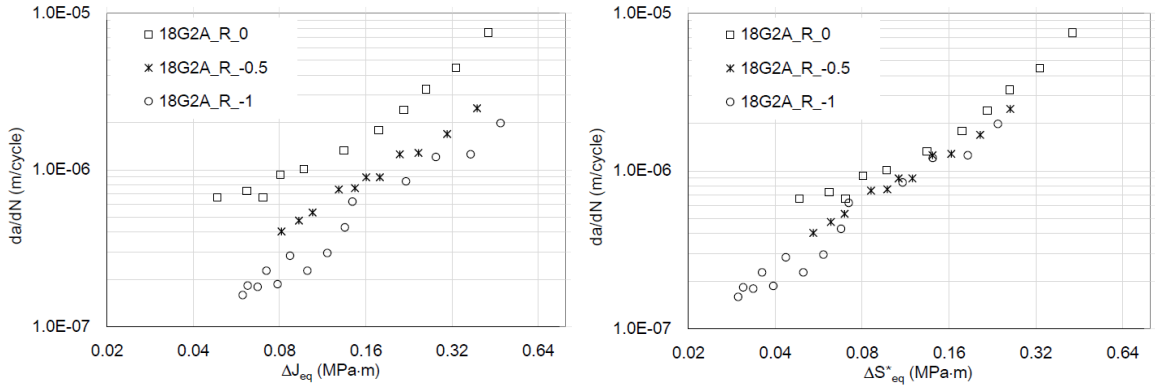

***Figure 1** – Mixed mode (I+III, loading angle α=30°) diagrams for S355 steel based on ΔJ (on the left) approach and new energy parameter ΔS^* (on the right)*

, Fatigue Behaviour of Bolted Connections Made of Thin Steel Plates. Experimental study

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Abstract. An experimental research about the fatigue behavior of single and multiple bolted joints made of thin plates made of S350GD steel has been performed within the FASTCOLD project. These bolted joints are being used for racking structures. Different parameters are investigated during experimental campaign namely geometric (single vs. multiple bolted joints), production (snuggle tight vs. preloaded bolts), manufacturing (punched vs drilled holes) and loading (different stress R-ratios). Experimental results were statistically evaluated and compared with existing S-N - EC3 proposal. The experimental S-N data showed an average slope consistently around m=8 which contrasts with m=3 from EC3. This discrepancy may be attributed to the higher importance that crack initiation plays in the bolted joints experiments and m=3 from EC3 is consistent with a fatigue crack propagation damage process. The EC3 Class 90 fatigue curve was very conservative for high to very high-cycle fatigue. However, for medium to high-cycle fatigue regimes, EC3 Class 90 fatigue S-N curve becomes unsafe. The preloaded bolts resulted into 10 times higher fatigue lives than snuggle tight bolts; drilled holes resulted in worst holes quality and consequently, the fatigue lives were approximately 10 times lower than punched holes. The multiple bolted joints revealed fatigue strength results consistent with single bolted joints: same slope and assuming 50% load carrying by each row of bolts similar fatigue strength was obtained.

, Mean stress effect and fatigue crack closure in material from old bridge erected in the late 19th century

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Abstract The problem considered in this paper is the structural integrity of old materials from the 19th century by means of fatigue crack growth problem. The authors present an overview of the fatigue fracture properties of old puddle iron members extracted from long-term operated bridges located in France. The fracture properties and fatigue crack growth results for 19th-century puddle iron are presented and compared with typical Kinetic Fatigue Fracture Diagram (KFFD) constructing methods. The presented results for fatigue crack growth rate description under mode I using ΔKapplied approach and ΔKeffective approach differs significantly using variable mean stress effect – R-ratio (0.05; 0.7). As it was demonstrated, the hysteresis loop analyses allow to obtain the estimated crack closure level. From the engineering point of view, there is a strong need for generalization of the KFFDs description using mean stress robust parameter involving local crack tip behavior for old puddle iron. Additionally, there are discussed the strengthening methods based on CFRP for this type of ancient materials in the light of the obtained numerical results for strengthened and non-strengthened puddle iron/steel specimens using CFRP patches using local approach.

, Study of the influence of the load ratio on the high cycle fatigue behaviour of double shear riveted joints

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Abstract : The understanding of the mechanical behaviour of hot riveted joints is a major issue for the maintenance of old metal structures. In particular, the fatigue resistance of these connections is paramount for the lifetime assessment of iron and steel railway bridges subjected to a large number of load cycles, the amplitude of which have also increased significantly with the increase in traffic during 100 to 150 years of exploitation. This paper discusses the influence of the load ratio on the high cycle fatigue behaviour (HCF) of double shear riveted connections subjected to tension. Modern steel (S235) test specimens have been specifically designed and manufactured. The results of a dedicated fatigue experimental campaign will be presented including two different load ratios. These results will be compared with the results of the literature. Failure modes will also been analysed.

, Effect of Pretreatment on Interface Stability and Morphology of Ni/Al Hybrid Foams by in situ Microcantilever Fracture Experiment

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Abstract Ni/Al hybrid foams are a new class of innovative cellular composite materials consisting of open-cell aluminum foams electrochemically coated with nanocrystalline nickel. They can be used for lightweight construction elements or as crash energy absorbers. The nickel coating strengthens the aluminum foam leading to e. g. ten times higher energy absorption capacities. Cellular materials such as foams provide a strong structure-property relationship. The macroscopic material properties strongly depend on the strut geometry and the micromaterial properties of the individual struts. The interphase stability between the coating and the substrate foam is the predominant factor in the strengthening mechanism of Ni/Al hybrid foams. Hence, micromechanical characterization is an important task for the design of components made of Ni/Al hybrid foams. A stabile interphase corresponds to a shear-stiff connection between substrate foam and coating. A worse interphase allows sliding between the two phases and hence reduces the buckling stiffness of individual foam struts resulting in lower strength and energy absorption capacity of the macroscopic foam.

The interphase stability was studied by in-situ 3-point bending tests of individual struts using synchrotron radiation at the EDDI beamline at BESSY II to elucidate local stresses directly at the interphase. The critical stress needed for a decohesion of the interface was increased by a chemically pretreatment of the aluminum foam before the electroplating with nickel. Even an increased critical energy absorption for interface cracking was revealed by FIB-prepared in situ microbeams during bending tests in the SEM after the chemically pretreatment of the base foam.

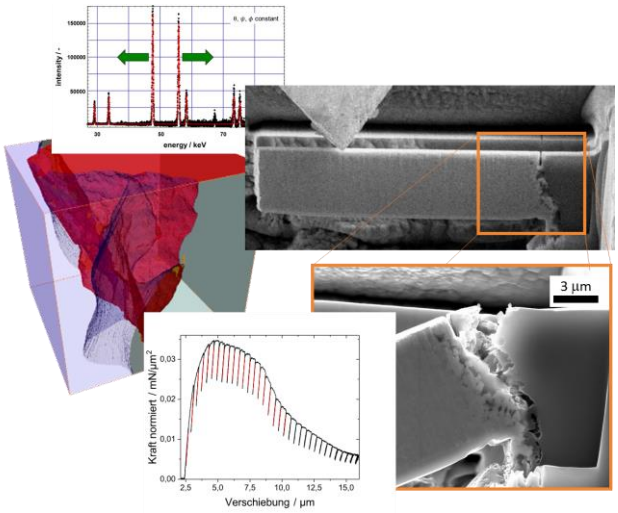

***Figure 1** – Energy dispersive diffraction analysis, FIB-tomography and microbending tests in the SEM revealing the interface stability of Ni/Al hybrid foams*

, Shear Strengthening of Reinforced Concrete Beams Using CFRP Wraps

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Abstract

The need to retrofit existing reinforced concrete (RC) structures have increased over the decades due to corrosion of steel reinforcement inside the concrete, neglect and overuse, and increased loading. Experimental and numerical studies in this research field showed that using Fiber-Reinforced Polymer (FRP) materials to strengthen RC members in shear, flexure, and column confinement applications is an effective method to retrofit RC structures. This strengthening technology has numerous advantages over conventional steel plating, such as providing high strength-to-weight ratio, versatility, durability, and ease of use to strengthen RC members. The purpose of this paper is to study the effect of strengthening shear deficient RC beams with externally bonded (EB) carbon fiber-reinforced polymer (CFRP) sheets with different wrapping configurations. Two shear strengthening wrapping schemes of CFRP sheets will be investigated; U-Wrapped and completely Wrapped. Although the completely wrapped scheme is more effective, however, due to its limitations, the U-Wrapped scheme became the most commonly used method in shear strengthening of RC structures. The drawback of this strengthening scheme is the premature failure caused by debonding of the CFRP laminates, without utilizing its full strength. The main aim of this study is to compare the performance of a U-Wrapped T-beam with two completely wrapped rectangular beams. The first strengthened rectangular specimen (WBR1) has a depth equivalent to the T-beam's web height, while the second strengthened rectangular specimen (WBR2) has a depth equivalent to the T-beam's total depth. In addition, a control T-beam and two rectangular beams were cast and tested as benchmark specimens. The experimental test results showed that the beam strengthened by U-Wrapped CFRP sheets increased the control beam's shear strength by 114.82%, while the increase in shear capacity of the completely wrapped equivalent WBR1 and WBR2 beams over their control unstrengthened specimens is 69.28% and 201.63%, respectively. In addition, the completely wrapped scheme provided more ductility compared to that of the U-Wrapped T-beam specimen, that failed by CFRP sheets debonding in a brittle manner. Thus, it could be concluded that an ideal way to increase the shear capacity and ductility of RC beams deficient in shear is to completely wrap the beams using CFRP sheets. However, if the completely wrapped scheme is not possible due to geometrical obstructions, U-wrapping scheme could be effective in increasing the shear capacity of RC beams but will fail in a brittle mode by sheet debonding without utilizing its full strength. Anchoring the CFRP U-Wraps could be a viable solution to enhance the performance of strengthened RC beams that should be investigated in future research studies.

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Analysis of transverse cracking in $[0/90]_{2s}$ composite laminates loaded in flexure with asymmetrical environmental conditions

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Abstract A modified Shear-lag model was used to predict the effect of the transverse crack on the stiffness properties degradation for $[0/90]_{2s}$ composite laminates under simple bending. Good agreement is obtained by comparing the prediction model and experimental data published by Smith and Ogin (2000). The material properties of the composite are affected by the variation of temperature and moisture, they are based on a micromechanical model of laminates. The transient and non-uniform moisture concentration distribution give rise to the transient elastic moduli of cracked composite laminates. This hygrothermal effect is taken into account to assess the changes in the normalised axial and flexural modulus due to transverse crack. The obtained results represent well the dependence of the stiffness properties degradation on the cracks density and operational temperature. The composite laminate with transverse crack loaded in simple bending is less affected by the hygrothermal condition than the one under tension loading. Through this theoretical study, we hope to contribute to the understanding of aged composite materials with matrix cracking.

, Propagation of long fatigue cracks in Ti6Al4V alloy produced by direct metal laser sintering

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Abstract Direct metal laser sintering (DMLS) is a very promising advanced technology for production of end-use components of complex shape for applications in aircraft, automotive industry or for implants into human body. The components are often exposed to cyclic loads during their use. Available knowledge on crack initiation and growth in relation to the DMLS processing parameters and post-processing heat treatment is not sufficient for the safe prediction of fatigue strength and for damage tolerant design. This contribution brings comparison of fatigue crack growth data for Ti6Al4V alloy manufactured by DMLS technology with different processing parameters and by different post-process heat treatments.

The growth of long fatigue cracks was experimentally determined on CT specimens. The crack propagation was investigated in three different orientations with regard to the building direction. The as build CT specimens were heat treated at three different temperatures, namely 380, 740 and 900 °C. The crack growth curves and the threshold values of the stress intensity factor ΔK_{th} for the crack growth were determined at room temperature in air for cycling characterized by the stress ratio R = 0.1 and 0.8.

It was found that the crack growth rate in the Paris region is identical for all three heat treatments. However, there is a clear effect in the near threshold region. The best resistance exhibits material with the heat treatment at 900 °C for 2h with subsequent cooling to 520 °C in Ar. The corresponding microstructure consists from lamellas of α + β phases with locally coarse α grains. The threshold stress intensity factor range for crack growth is ΔK_{th} = 3.4 $MPam^{1/2}$ for R = 0.1 and 2.0 for R = 0.8.

The obtained results are discussed in terms of microstructure and residual stresses. The heat treatment at 740 and 900 °C results in a microstructure without directionality on a microscopic scale. This explains the independence of the fatigue crack growth rate on the angle between the propagation direction and the build direction. The heat treatment at 380 °C is sufficient to remove long range residual stresses; however the large scatter of crack growth data is a characteristic crack growth feature.

The crack growth resistance was compared with the data for conventionally manufactured material. The results show that with suitably chosen DMLS processing parameters and suitable heat treatment the Ti6Al4V alloy produced by this technology is well comparable with conventionally manufactured material.

,Investigation of mechanical properties and microstructure of X60 line-pipe steel

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Abstract A segment of seam pipeline with an outside diameter (OD) 813 mm and wall thickness (WT) 11.2 mm, operating since 1974, had been used for investigation mechanical properties and microstructure – Fig. 1. The results of the tensile test show that prescribed values of minimum yield point, ultimate tensile strength and ductility were reached in all specimens. Charpy V-notch test was carried out on the base metal, heat affected zone and seam weld at temperatures 40, 20, 0, -20, -40 and -60 °C. In the case of base metal, L-T orientation had higher upper shelf energy and ductile-brittle transition temperature (DBTT) than T-L orientation as is typical for hot-rolled materials. The lowest impact energy was revealed in the heat affected zone and seam weld due to the presence of heterogenic microstructure that consisting of grain boundary ferrite, polygonal ferrite and Widmanstätten ferrite.

Figure 1 – *The segment of pipeline used for investigation mechanical properties and microstructure*

, Acoustic Emission-Based Similarity Analysis: A Baseline Convergence Algorithm

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Abstract

The primary objective of condition monitoring (CM) is to determine the operational state and health of a machine through continuous or periodical data collection, analysis and interpretation. Detecting and following the evolution of defects, as an important part of predictive maintenance activities, can give operators the chance to act early enough for the faults to be corrected and be able to schedule maintenance intervals for low cost repairs.

Independent of the technique used, such as acoustic emission, vibration analysis, ultrasonic guided waves, or any other methods of monitoring, a common and sensitive aspect of condition monitoring is not only the baseline definition, but also the amount of data necessary for defining it.

Warning and action limits are subjective to change, and are not only influenced by the failure mechanism and the machine itself, but they can also differ from one machinery to another being even from the same kind. Therefore, the process of baseline generation can have different duration or can require different amount of data for each case alone.

The main purpose of this study is to present a convergence algorithm, indicative of a representative baseline for a specific mechanism at a certain point in time. This implies that the sample of data collected and called a baseline includes sufficient information for characterizing the running state of the mechanism, being stable enough (i.e. if increasing its size does not have any sensible effect) for allowing subtle changes to be detected.

The convergence criterion evaluates not only a minimum number of measurements, but also a maximum for ensuring a valid use of the data and thus avoiding a defect to be diluted within a large data sample.

The paper includes a case study of continuous Acoustic Emission using the convergence methodology applied on a low-speed rotating mechanism. The process of baseline generation and the identification of deviations from normal operating conditions are described, aiming to create an alarm when the signals captured from the running process have moved away from their mean or when the signal variability has increased.

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Effect of manufacturing residual stress on the fatigue life of railway wheels for heavy-haul transportation

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Abstract: The present work aims to compare the effect of the residual stress from the thermal treatment process on the estimate of fatigue life of railway wheels - class C, with and without residual stress. The finite element method in a 3D numerical model is used to calculate that thermal treatment process and the rolling contact between rail and wheel. With the stresses calculated in this region, the study estimates the life under fatigue until a crack arises. The crack, when propagated, can give rise to shelling, which is one of the types of failures with significant economic importance for the railroad maintenance. The main contribution of the model is the elastoplastic approach, adding residual stresses from the thermal treatment process of railway wheels. The ABAQUS software is used for the numerical processing in this paper, in parallel with specially developed techniques to reduce the computational cost without causing loss of accuracy of the results. The fatigue life of the railway wheel until the crack arise is determined by of the high-cycle fatigue criterion of Dang Van-modified. With the hypothesis that the wheel radius does not change during rolling, the elastic shakedown phenomenon occurs in a few loading cycles. With the field of stress variation, the high cycle life for the wheel is estimated, both with and without residual stresses from the thermal treatment process. The results of the numerical simulation showed that the Von Mises stresses in railway wheels with thermal residual stresses are lower than in wheels without thermal treatment. The elastic shakedown phenomenon happened in three load cycles for the first condition and in four load cycles for the second one. This small difference caused by the thermal treatment has a significant effect in the number of cycles of fatigue life. The modified Dang Van's fatigue criterion showed that railway wheels with thermal treatment reach 43,2% more life than railway wheels without it.

, Analysis of the crack location in notched steel bars with a multiple DC potential drop measurement

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Abstract The direct current potential drop (DCPD) technique is a frequently used method to measure crack propagation in metallic materials. With a single potential probe attached to the specimen, the size of an initiated crack can be estimated. Therefore, this method is used in crack propagation experiments to determine the crack propagation rate. However, with a single potential probe it is difficult to detect small cracks and impossible to determine the location of the initiated crack.

In the present study, three potential probes were attached to cyclic loaded notched steel bars. For the case of an initiated single crack, this experimental set-up delivers different potentials depending on the distance of the probe to the initiated crack. A geometric model was developed to determine the position of the initiated crack from the increase of the individual probe signals relative to each other. In this model, every potential drop signal is treated as a vector. In the beginning of the experiment, without a crack all three vectors have the same length (see Figure 1a). As a result, the vectors span a horizontal plane. With the initiation of a crack, the vectors elongate by different amounts and the spanned plane tilts away from the propagating crack (Figure 1b).

The experimental verification of the model has shown that in case of a single crack, the position can be determined clearly, even in the early stages of crack propagation. Moreover, the sensitivity of the potential drop measurement for the detection of an initiated crack is enhanced by this method.

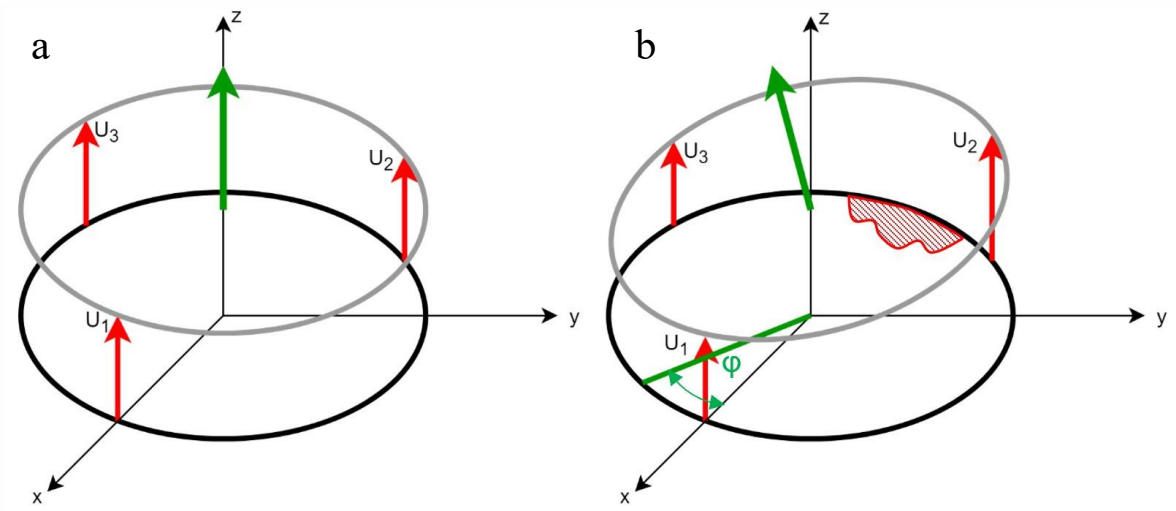

***Figure 1** – Model for determining the position of an initiated crack*

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NDT integrity engineering – a new discipline

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Abstract: NDT integrity engineering combines materials science with fracture mechanics to engineer a non-destructive evaluation process that would guarantee safety and reliability, or integrity, of engineering structures and components. It is primarily focussing on non-destructive testing / evaluation methods. Its knowledge basis encompasses all disciplines which contribute to establish any integrity related decision.

Core knowledge includes the physical bases of the major NDT methods; the current tendency to provide early detection of materials degradation; the structural health monitoring; the impact of the development of information technology and microelectronics on NDT; globalization of NDT; and many other issues. The knowledge should cover also the awareness of the physical fields arising in the component during operation, including the basics of analytical and numerical methods of their calculations. From these operation and accident loading, stress / strain status, stress intensity factor and other operational conditions can be calculated. The properties of structural materials, i.e. the „material's response" to loading and environment, the ageing effects; the potential ageing processes such as embrittlement, loss of toughness, fatigue, corrosion, creep, wear and some more, and their effect on the component integrity.

Motivation of emphasizing NDT integrity engineering is that in the recent decades, enormous efforts have been provided to increase the capability of assets of high value and of high potential risk such as power and process plants, offshore platforms, bridges leading to their more intensive utilization. It is equally important to operate the engineering assets safely, and thus, saving human and environment. The presentation intends to describe the needed profile of the NDT integrity engineer.

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Corrosion and tensile behavior of 316L stainless steel concrete reinforcement in harsh environments containing a corrosion inhibitor

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Abstract The electrochemical performance of 316L stainless steel rebars in a solution of pH~8 consisting of Ca(OH)2 and fly ash (0-25 wt.% of the dry mixture) in an acid rain simulating solution was investigated by reverse polarization. Concrete cubes containing 0-25 wt.% fly ash and reinforced with 316L or 304L rebars were subjected to salt spraying. The salt spraying-due degradation of the rebars was studied by tensile testing. The beneficial effect of fly ash up to 20 wt.% content on the electrochemical behavior of 316L rebars is demonstrated. However, this trend is reversed at 25 wt.% FA. The tensile behaviour of 316L and 304L rebars after 2 m of salt spraying was not significantly affected by the fly ash presence. 316L and 304L embedded rebars performed similarly on tensile testing after salt spraying.

,A Review of Fatigue Performance of Bolted Connections in Offshore Wind Turbines

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Abstract Flanged bolted connections are used in offshore wind turbines to connect the monopile to the transition piece, and the transition piece to the tower. Forces and moments generated by the effects of winds, waves and currents subject these connections to variable amplitude cyclic loads in the harsh offshore environment. Areas such as bolt threads in flanged connections are vulnerable to fatigue cracking and failure as a result of in-service conditions and their structural integrity is influenced by coatings, lubricants and manufacturing tolerances. One of the key challenges in fatigue life assessment of large scale bolts (e.g. M72) used in offshore wind turbine is the lack of experimental data points from which new fatigue design curves for larger size bolts can be derived. This paper presents a review of the main challenges in fatigue life assessment and the factors affecting the fatigue performance of M72 bolted connections. Moreover, the existing standards and guidelines, along with different fatigue assessment methods for offshore wind turbines are collated and discussed in terms of their suitability for fatigue life assessment of M72 bolted connections in offshore wind turbines. Last but not least, recommendations have been made to improve the current best practice adopted in the offshore wind industry and subsequently potential areas for further investigation are proposed for future research on large scale bolted connections.

Mixed Mode Crack Growth in Functionally Graded Material Under Three-Point Bending

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Abstract

Functionally graded materials, FGM, permit tailoring of the material volume fractions to extract maximum benefit from their in-homogeneity. Such materials offer great potential for components which operate under severe thermal or mechanical loadings, such as spacecraft heat shields, plasma facings for fusion reactors, crucial jet fighter structures and engine components. In the present work, polyester matrix reinforced by varying glass fiber distribution was used to obtain polymeric composite FGM. The hand lay-up technique was adopted to manufacture the FGM. The fracture toughness of glass fiber/polyester FGM under three point bend beam was measured. The mechanical properties, such as tensile, compressive, in-plane shear, and flexural strength were determined experimentally. Pre-U notch of 3 mm depth with seven different inclination angles was made to study the mixed mode fracture toughness of FGM at different mode-mixities (K_{II}/K_I). It is found that mixed mode fracture toughness of FGM increased with increasing the ratio of mode-mixities. For a high value of mode-mixity, notch insensitivity phenomenon has been observed as shown in Fig. 1.

Figure 1 - Notch insensitivity phenomenon in FGM

, Notch tensile strength of carbon fiber/epoxy composite plate with a center hole under static and cyclic loading

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Abstract

The tensile and fatigue properties of epoxy reinforced with 68 volume percent carbon fiber, CFRP, have been fully investigated. The effect of the presence of an open circular hole on tensile, fatigue residual strength, and fatigue strength of CFRP plates was studied experimentally and numerically. The results of pin bearing, i.e. bolt-loaded holes, tests were also investigated and evaluated. A three-dimensional orthotropic-elastic finite element code was developed to calculate the stress concentration factors of open circular holes or bolt-loaded holes in composite materials.

The modulus of elasticity, tensile strength, and maximum elongation of CFRP are approximately equal to the values found in the technical data sheet of the supplier. A rule of mixtures type relation is adequate to predict the modulus of elasticity of such CFRP plate. This may be attributed to the high mechanical properties and high volumetric content of the fibers compared with the matrix, i.e. there is a marginal contribution of the strength of the matrix or the fiber-matrix interfacial bond strength. Based on the net stress analysis, there is no difference between the mechanical behavior of smooth and open-holed specimens, i.e. notch insensitivity. This is due to the incapability of the matrix to transfer the load from the discontinuous part. The same behavior was also found under cyclic loading. Due to the weakness in the bond between the fiber and matrix or in the shear strength of the matrix compared with the tensile strength of the fiber, the failure mode of all tested bolt-loaded unidirectional CFRP plates is shear-out. Further, the strength of such bolted joints is mainly dependent on the size of the contact area between the hole and the bolt.

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Fatigue Behavior of AA2198 in Liquid Hydrogen

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Abstract

Today, design requirements and cost targets require a better knowledge about material properties and behavior. Especially in challenging technical fields, the knowledge about material properties is a key issue to achieve design requirements like lowest component mass at highest structural integrity. A typical example is the design of liquid hydrogen propellant tanks.

A possible material for hydrogen propellant tanks is the aluminum alloy AA2198. The present investigation shows the results of tensile and fatigue tests with aluminum alloy AA2198 under liquid hydrogen (LH2) and ambient conditions.

Tensile and fatigue tests were performed with flat specimens using a servohydraulic testing machine with a load capacity of 100 kN equipped with a LH2 cryostat. Tests under ambient conditions were conducted using a different servohydraulic testing machine with a load capacity of 63 kN. All fatigue tests were performed under load control at a frequency of 20 Hz and a stress ratio of R=0.1. The Gecks-Och-Function [1] was fitted on the measured cyclic lifetimes.

The tensile strength in LH2 was measured to be 46% higher compared to the value determined at ambient conditions and the fatigue limit raises about 60%. Both S-N curves show a distinct S-shape but also significant differences. Under LH2 environment the transition from LCF- to HCF-region as well as the transition to the fatigue limit is shifted to higher cyclic lifetimes compared to ambient test results. The investigation of relevant crack surfaces also show distinct differences comparing ambient and LH2 conditions. Obviously, these differences are responsible for the differences in the fatigue behavior.

The obtained knowledge from the investigations prove that the exact determination of material properties require tests under realistic conditions in terms of chemical environment and temperature. It is not possible to receive usable design data by simply extrapolate from room temperature data.

[1] Gecks, M., Och, F., Ermittlung dynamischer Festigkeitskennlinien durch nichtlineare Regressionsanalyse, MBB-Bericht UD-208-77, (1977).

, Determination of dissipated energies during fatigue tests on Copper and AA7475 with Infrared Thermography

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Abstract During fatigue loading of metallic materials energy is dissipated leading to a heating of the specimen. This temperature increase can be used to determine the fatigue limit of the material. Beside the global temperature increase, the thermoelastic stimulated Lock-In thermography proposes to determine the dissipated energies. In this method, the measured temperature signal is dissected into sine waves coupled with the loading frequency. The thermoelastic effect is described with a wave with the loading frequency (E-Mode), twice this frequency is assigned to dissipated energies (D-Mode). Previous investigations have shown that temperature changes caused by dissipated energies cannot be described with a sine function with the double loading frequency and therefore a quantitative determination based on a Lock-In evaluation is not possible. Therefore the appearence of D-Mode amplitudes can just be used as a qualitative criterion for non-linear effects caused by dissipative energies.

In this work, detailed studies of the temperature change caused by dissipative energies within a loading cycle were performed on oxygen free copper and the aluminum alloy AA7475 T761. The temperature changes in a loading cycle were recorded with a high speed thermography camera. To determine the temperature changes due to dissipative effects, the thermoelastic effect is substracted from the measured temperature. The corresponding thermoelastic constant is determined in an experiment with a pure elastic loading of the specimen.

Force controlled experiments showed that the heating effect in a cycle decreases until a equilibrium temperature is reached. This clearly indicates a direct relation between the strain and the heating effect within a cycle. Compared to pure tension loading (R>0) under fully reversed loading (R=-1) a higher heating can be observed, caused by an additional heating effect in compression. The equilibrium temperature increases with the loading frequency. This effect can be contributed to a decreasing cooling time within a loading cycle. The amount of dissipated energy was found to be independent of the loading frequency. The temperature change within a cycle can be described by a simple model basing on the mechanical and physical properties of the material.

The investigations have shown that the detailed analysis of the temperature change within a loading cycle can provide interesting information about the amount and the time when energy is dissipated in a loading cycle. This enables a more detailed study of the fatigue behavior of metallic materials and can provide valuable data for the prediction of the cyclic lifetime.

, Numerical simulation of soil stability during artificial freezing

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Abstract Artificial ground freezing is a universal and efficient method that is used in construction of engineering and civil buildings in fluid-saturated soft soil. When applying the method an ice soil retaining structure is created. The structure provides temporary support of ground and groundwater control.

Ground freezing is implemented by a series of freezing wells that are drilled around a designed structure. During the process the pore water freezes and as a result a volume of the soil increases by 9%. The expansion of the soil leads to the rise of mechanical pressure and soil swelling, so a mechanical state of the soil changes. This alteration could induce additional loadings and fracture of the freezing wells and the buildings under construction. Especially, dangerous loadings could arise on the boundary of two soil stratums with different mechanical and thermo-physical properties.

The present study is devoted to a numerical simulation of a stress-strain state of water saturated soils during the process of artificial freezing. The simulation has been performed by originally developed thermo-hydro-mechanical model [1]. The model consists of the energy balance equation with the first-order phase transition, the mass balance equation, Darcy's law for filtration flow and the equilibrium equation. Skeleton of soil is assumed to be isotropic elasto-plastic material that undergoes small deformation. Interaction between fluid and skeleton is modeled by Biot theory. Plastic strain is described by associated flow rule with yield surface given by Drucker-Prager criterion. Also additional contributions to strain from thermal expansion and swelling of soil are taken into account.

On the basis of the developed model a mechanical state of an ice soil retaining structure has been studied. As a result of the study stress and strain distributions in the soils adjacent to a freezing well and the shaft wall have been determined. It has been shown that during artificial freezing plastic strain appears at the interface phase transition. Soil swelling induces an increase in stress around the freezing well and the shaft wall. Mechanical pressure within the ice soil wall has nonhomogeneous distribution. A maximum value attains in the soil stratum with the highest rate of the freezing process. Also an increase in the pressure is observed at the boundaries of soil stratums.

This research was supported by 17-11-01204 project (Russian Science Foundation).

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,Fatigue crack growth behavior of laser-shock processed 2024-T3 aluminum

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Abstract Various surface modification techniques are aimed at enhancing the resistance to wear, corrosion and fatigue of structural alloys. Among them, laser shock processing (LSP) is a competitive process due to its favorable combination of resulting microstructure, surface finishing and residual stress field, thus improving the damage tolerance of critical parts. In LSP, a pulsed laser is focused on the target by an optical set, the target surface layer evaporates and, by absorbing energy from the laser, is immediately ionized. The expansion of the plasma is confined by a transparent layer (usually water) and its collapse generates a shock wave, which in turn propagates into the target metal, plastically deforming the material and inducing deep, high magnitude compressive residual stresses. In the conventional process, a thin ablative layer is placed between the water overlay and the target surface in order to enhance the beam coupling efficiency (absorptivity). More recently, LSP without coating (LSPwC) has been gaining ground, using lasers with lower energies (a few Joules or less), shorter pulse duration, smaller laser spots and higher surface coverage per shot. In the present work, LSPwC treatment was performed in both sides of pre-cracked 4.5 mm thick compact tension specimens of aluminum alloy 2024-T3. A pulsed (9 ns) Nd:YAG laser system operating in the second harmonic (532 nm) at 10 Hz repetition rate and with pulse energy of about 270 mJ was positioned with a 500 mm focal distance lens in order to conduct LSP with an estimated power density of 5.2 GW/cm^2 and two distinct overlapping rates: 50% and 75%. Figure 1 shows a fatigue specimen with LSP footprint ahead of pre-crack. The objective of the work was to investigate the effect of the LSP and cyclic load condition on the crack closure behavior and fatigue crack growth rate shown by the specimens. The LSP samples were evaluated as for the resulting microstructure and hardness, surface roughness and residual stresses. The fatigue crack growth tests were conducted at high and low stress ratios and the linear-quadratic spline method was employed in the crack closure calculations.

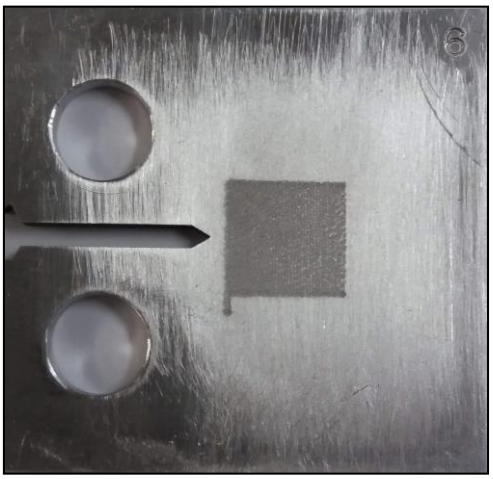

Figure 1 - *View of the fatigue specimen with LSP impression ahead of pre-crack.*

The most frequent failure causes and modes in super ferritic stainless steels: are they really super?

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Abstract Ferritic stainless steels were discovered in the USA in 1911 and in 1915 it was suggested using these alloys in turbines, which is still used by project engineers. It is common to classify ferritic stainless steels (FSSs) according to their "generation" and the super ferritic stainless steels (SFSSs), containing about 0.02% C, Cr above 25%, Ni and Mo between 2 and 4% and eventually Nb or Ti, are the fourth generation of FSSs. The favorable combination of mechanical strength and corrosion resistance of SFSSs make them candidates for applications in some industrial segments such as chemical, petrochemical and desalination. Despite their usage, the SFSS components might be subjected to various types of mechanical and environmentally induced failures during their life cycle, especially when the component is exposed to temperatures above 300°C, which might promote the precipitation of stable and deleterious phases. For instance, the precipitation of sigma, alpha-prime and Laves phases might induce the premature failure of SFSS components due to the mechanical embrittlement of the microstructure during thermal exposure (either in processing or service). Additionally, the ferrite phase features a ductile-to-brittle temperature, which defines the lower service temperature of SFSS components. In this sense, the main properties of SFSSs will be compared with the properties of duplex stainless steels (DSS) and austenitic stainless steels (ASSs) to provide the reader a broader view about boundary conditions for the selection and use of SFSSs for the production of engineering parts. The main phase transformations and microstructures of the SFSSs will be concisely presented and microstructural, fractographic and crack propagation characterization of selected in-service failures will illustrate the role of these stable and deleterious phases on the life of SFSS components.

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Crack-Detection in old riveted steel bridge structures

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Abstract Although many riveted bridge structures made of old mild steel constructed in the period between 1880 and 1940 are still in use after decades of service, there is usually no need to replace them. When assessing these existing steel structures to decide on necessary rehabilitation or reinforcement measures engineers particularly requires information about the remaining cyclic lifetime of the material.

The assessment of the fatigue resistance of these structures is currently based on normative notch details, S-N-curves and a linear damage accumulation hypothesis. If sufficient remaining cyclic lifetime cannot be evaluated with this method, for railway bridges an operating time interval verification based on fracture mechanics is carried out. Thereby, a fatigue crack at the edge of the rivet hole is assumed which extends 5 mm beyond the edge of the rivet head and can thus be found visually during a bridge inspection. The potential of crack initiation and crack growth below the rivet head is not yet included in the assessment. Therefore, this part of fatigue life is the subject of a current research project. Initial studies have already shown that the growth of cracks at holes is significantly retarded by the prestressing force of the fasteners (rivets or bolts).

To include the early phase of crack propagation in the assessment of a steel bridge, it is necessary to detect reliable or exclude such a small crack in the structure. In this early phase of crack growth, however, the crack at the rivet hole is still covered by the rivet head. Recent investigations of the authors at parts of an aircraft wing [1] indicates that fatigue cracks can be detected safely with a length less than 2 mm using Lock-In thermography. It was also possible to detect cracks under the surface. In this actual study the applicability of thermoelastic stimulated lock-in thermography for fatigue crack detection at riveted steel structures will be evaluated. Therefore, tests were performed on fatigue test specimens (see figure 1) with fatigue cracks on the edge of the holes, rivet-like bolts and typical corrosion preventive coatings.

Figure 1 – *Uncoated test specimen for crack detection with a rivet-like bolt*

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, Effect of Biaxiality on Engineering Critical Assessments

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Abstract

Common practice for the integrity assessment of structures, follows the use of Fitness for Service procedures, such as BS7910/R6 (BSI 2013; EDF Energy Nuclear Generation Ltd. 2000). There are many common structures (e.g. pressurized components, pipes) that are under biaxial loading. Even though the load biaxiality has been proven experimentally to have an effect on both the fracture toughness and the limit load of a component, the influence of biaxial stresses is not directly addressed in the procedures. In order to address the effect of biaxiality on engineering critical assessments, BS7910 and R6 fitness for service procedures are applied to four biaxially loaded wide plate tests previously conducted on A533B steel (Phaal, Andrews, and Garwood 1995). The plates had been loaded in biaxial tension, with a biaxiality ratio ($k=P_2/P_1$, see Figure 1), of 0.5 and 1, while the temperatures of the plates tested correspond to lower shelf (-100 ºC ─ -103ºC) fracture toughness. The assessments include failure assessment lines (FALs) created using the more basic approaches (Option 1 and Option 2), which depend on a knowledge of the tensile properties of the material, as well as the structure and load history - Option 3. In order to obtain the Option 3 FAL, finite element analyses are conducted for the specimens. The tests are first assessed with the proximity to plastic collapse (L_r) and fracture (K_r) being calculated with the use of the fracture clauses of BS7910/R6, which do not take into account the effects of biaxiality. The convectional assessment is then followed by a more detailed assessment for the equibiaxially loaded specimens using Annex N/ Section III.7 of BS7910 and R6 respectively, which incorporate correction of fracture toughness in relation to constraint. The results presented in the study show that more advanced assessments, that take constraint into account, provide higher accuracy, while FEA conducted on specific tests allow a comparison between the analytical and numerical results.

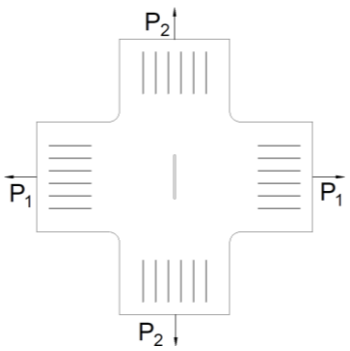

Figure 1*- Biaxial tests studied*

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Determination of Fracture Modes in Novel

Aluminum-Steel Dissimilar Resistance Spot Welds

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Abstract With increasing demands to improve vehicle fuel economy, multi-material body structures are increasingly utilized in the automotive industry for structural lightweighting purposes. These multi-material structures pose challenges for dissimilar material joining, particularly aluminum to steel. General Motors (GM) developed a new resistance spot welding technique using a multi-ring domed electrode and multiple solidification weld schedules to address these challenges. In aluminum-steel resistance spot welds (RSWs), an iron-aluminum intermetallic compound (IMC) layer is formed at the interface and its strength affects tensile shear specimen fracture modes, i.e. interfacial versus pull out fracture. Based upon the experimental heat affected zone (HAZ) and IMC shear strengths using a new mini-shear test specimen, it was observed that it was not suitable to use the critical weld nugget diameter of $4\sqrt{t}$ recommended by the American Welding Society (AWS) to determine the fracture modes of these unique aluminum-steel spot welds. In the present study, a new formula is derived to calculate a critical aluminum-steel weld nugget diameter based upon experimental results. The calculated critical weld nugget diameters were then compared with experimental results to predict fracture modes for aluminum-steel stack-ups with different sheet thickness. The results are in excellent agreement with the observed experimental fracture modes (see one of the examples in Fig. 1).

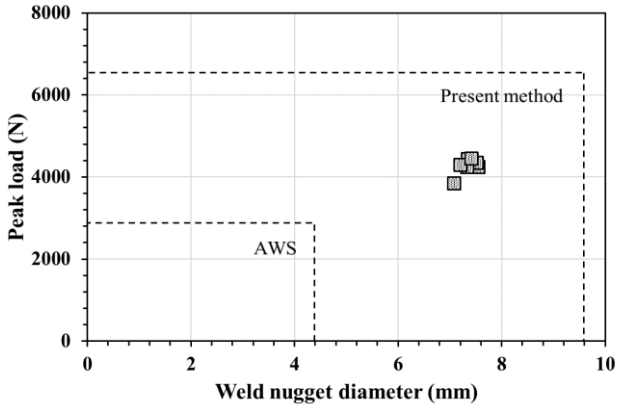

Figure 1 - *Prediction of fracture modes using present method and AWS method for 1.2 mm AA6022-1.2 mm LCS stack-ups. The zone inside the dash line represents interfacial fracture and outsides represents pull out fracture. Experimental data exhibits interfacial fracture.*

, REGISTRATION OF LOCAL DAMAGE BASED ON THE USE OF FIBER-OPTIC STRAIN SENSORS AND NUMERICAL SIMULATION RESULTS

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Structural health monitoring of the construction, especially during the operational load, is an important and relevant task. Permanent collection of information about the current state of the object in real time provides the data necessary to prevent breakdowns caused by aging and the effects of external factors. Objects made from polymer composite materials (PCM), along with numerous advantages, have a probability of unexpected damage development during operation. That is why it is necessary to create monitoring systems that allow to detect damages in the early stages of appearance, before they lead to the destruction of the construction.

Implementation of fiber-optic strain sensors (FOSS) between the PCM layers at the stage of technological process of layers stacking has the potential of creation defect identification systems. Strain measurement is one of the main tasks when using FOSS in the PCM. The sensitivity of FOSS on Bragg gratings to changes in the stress-strain state of a material makes it possible to detect small-size damages, since they cause changes in the strain fields in the material.

This study presents a technique that allows you to capture defects that occur in a structurally similar polymer composite sample in the form of a flange, as well as to monitor their growth and development. The technique includes a preliminary numerical simulation of the stress-strain state of the flange, the definition of monitoring areas with the mandatory location of sensors in the stress concentration areas and in moderate stress areas, as well as an analysis of the relationship of sensor readings. To test this technique, a tensile experiment was performed on flanges made of PCM.

It was noted that the defects (in delamination form) that appear along the edge with increasing loads, which are a zone of stress concentration, are unevenly distributed. This is a natural consequence of the asymmetry of the sample manufacture and its loading. Experimental results from various sensors in the form of the dependence of the strain values on the load values show that as the load increases, the ratios of the strain values change as the defects appear. Experimental results from various sensors in the form of the dependence of the strain values on the load values shows that as the load increases, the ratios of the strain values change as the defects appear.

The appearance of defects was recorded visually. It should be noted that large values of strains, as well as in a numerical experiment, was recorded by sensor located in the zone opposite to the area where the largest defects occur.

This study was supported by the Russian Science Foundation (project No. 15-19-00243).

, Numerical Modeling of the Capillary in the Bragg Grating Area, Ensuring Uniaxial Strain of Embedded Fiber-Optic Strain Sensors

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There is a direct correspondence between the relative change in the resonance wavelength of the reflected signal caused by a change in the Bragg grating wavelength and strain along the optical fiber only under the condition of uniaxial strain of the optical fiber when single-mode fiber-optic strain sensors (FOSS) on Bragg gratings are used. In the general case a complex-stressed state is realized in the Bragg grating zone when an optical fiber is embedded into a material, in particular, into a polymer composite material (PCM). In this regard, the problem arises of providing uniaxial strain of the Bragg grating when FOSS is embedded into material. To do this, it is necessary to change the parameters of the material surrounding the fiber, which, in a constructive implementation, means the use of an additional coating (capillary) around the fiber in the area of the Bragg grating. Such coating may be uniform or non-uniform.

Additional coating is characterized by the geometric dimensions and mechanical characteristics of an isotropic material. The case of a homogeneous coating includes the option of having a cavity with the dimensions of an additional coating. For an additional coating, various variants of its interaction with an optical fiber can be realized, from ideal contact to ideal slip along the contact surface. An inhomogeneous shell is represented by an outer coating of an elastic isotropic material and an inner cavity between the outer coating and the optical fiber.

The additional coating must ensure the fulfillment of two conditions: the realization of a uniaxial stress state in the Bragg grating area and an adequate strain transfer from material to the sensors, i.e. similar values of strains in the fiber along its length and strains in the material in the direction of the fiber. In addition, it is necessary to estimate the additional stress concentration in the vicinity of the optical fiber caused by the use of a capillary and evaluation of the performance of the capillary functions in the range of operational loads.

The parameters of the additional coating are selected by numerical modeling based on the calculation of the stress-strain state of a fragment of a polymer composite material in the form of a cube in which an optical fiber with an additional coating is embedded. The dimensions of the cube significantly exceed the length of the additional coating. For this task the most unfavorable loading option in which external influences are perpendicular to the fiber, is considered. The results associated with the features of the cross-sectional geometry of the capillary, when a FOSS is embedded into anisotropic material, are presented.

This study was supported by the Russian Science Foundation (project No. 15-19-00243).

, Fatigue assessment of amplitude-modulated non-stationary random vibration loading

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Abstract Designing mechanical structures exposed to random vibration loading compromises two central challenges. The first is to abstract or to define representative load assumptions. The second is to efficiently process these load assumptions in a fatigue assessment. Both are primarily a matter of statistical load description.

Defining random loading via the power spectral density (PSD) combines an effective statistical description with the ability to efficiently perform fatigue analysis for linear structures using frequency-domain methods (e.g. Dirlik). The PSD is a fundamental tool of vibration fatigue depicting the amplitudes of all harmonics contained in a load series. It covers a full stochastic description for stationary Gaussian random processes. Measured in-field vehicle vibration usually differ significantly from this assumption. In particular, the constant change of operating, environmental or excitation source conditions results in a varying intensity of the vibration process. Employing the PSD for such non-stationary loading results in the averaged power spectral density. A replication of the loading solely based on the averaged PSD generally has lower amplitudes than the referencing measured load series. Thus processing the PSD for non-stationary loading leads to non-conservative deviations for the lifetime estimation.

We propose an extension of the well-known frequency-domain fatigue estimation for non-stationary load series. It is based on a model associated with amplitude modulation. A PSD estimated from a measured load series functions as the elementary vibration process. To ascertain for the non-stationarity the vibration process is modulated by a low-frequent function that represents the varying intensity due to changing conditions. As the elementary vibration process is generally broadband the model is resumed as an elementary vibrational ‘carrier-noise’ that is amplitude modulated by the varying intensity.

The central idea is to decompose a real non-stationary loading into a stationary Gaussian component (carrier-noise) and the information about the varying intensity (modulating signal). The former can be evaluated using the efficient frequency domain methods; the latter withholds the full information about the deviation from a stationary Gaussian realization. The varying intensity is assumed to be of random nature and thus is described by spreading measures analogous to statistical moments. This contribution will present *(i)* its derivation from a measured load series *(ii)* how to relate these to the frequency axis to test for the model *(iii)* its influence on fatigue damage *(iv)* how to reduce test times reproducing the loading on experimental set-ups. Thus the proposed contribution gives a comprehensive framework for non-stationary loading under the assumption of an amplitude-modulated origin.

Embedded ultrasonic transmission sensors and signal processing techniques for structural change detection in the Gliwice bridge.

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Abstract: Embedded nondestructive technique (ENDT) is an emerging technology that will allow changing the traditional ultrasonic method to embedded structural health monitoring (SHM) systems. It will be an era for embedded structural health monitoring such as those imagine for the Integrated Structural Health Management (ISHM) system. ISHM refers to self-acting methods for determining adverse changes in the structural material.

Most of the bridge decks are made generally of reinforced concrete, and the concrete is a heterogeneous material with non-linear elastic properties. Therefore, material degradation is an important issue with concrete structures. Loads, such as temperature and traffic, could result in progressive and continuous micro cracks, which leads to the increased permanent strains and decreased the stiffness of the structure. Hence, from the elastic properties of the concrete, we can find the structural changes in the material. The main goal of this study is to detect the signal disturbances referred to possible internal defects and damage using the processing of acquired ultrasonic signals. In our research, we use new ultrasonic transducer. These ultrasonic sensors and traditional strain gauge sensors installed in the Gliwice bridge during construction. Since acquired signals from the mentioned sensors are raw signals. Therefore, the signal processing algorithm is developed for the ultrasonic sensor array to detect changes in the reinforced concrete structure and compare the detection capability with traditional strain gauge sensors. The signal processing methods being used to denoising, compensate DC offset, crosstalk, and the feature extraction. For better recognition of the structural changes of reference state and intermediate state in the mechanical properties of the material, need to be analysed, e.g. using cross correlation method. From traditional measuring, direct waves are considered (first echo at the receiver in most cases). However, lots of other reflected waves, which arrive much afterwards at the receiver, hold efficient information as this waves coming from larger areas of the structure. From the input echo, and the back surface echo of longitudinal and transverse waves, it is easy to calculate the direction of a linear relationship of velocity, and then determine the elastic constants which allow us to describe the changes in the structure and properties of materials. Therefore, signal processing techniques such as split spectrum technique are used to extract the correlation coefficient of the longitudinal and transverse wave packages, which allow us to determine the location and signature of the changes in the material. The applied embedded sensors together with proposed signal processing algorithms can detect changes in concrete structures as good as traditional strain gauge sensors, which was verified in laboratory and in-field experiments. In further studies, we take into consideration an automatic change detection application.

This research is a part of the INFRASTAR project (European Union's Horizon 2020), dealing with advanced monitoring such as load, temperature and strain measurements for fatigue damage assessment in bridges and wind turbines.

Flexural Behavior of RC Beams Strengthened with Bolted and Bonded Aluminum Alloy

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Abstract

Enhancing the flexural capacity of reinforced concrete (RC) beams using externally bonded Fiber Reinforced Polymers (FRP) and steel plates has been a common practice over the last three decades. The use of FRP, as an externally bonded strengthening material, permitted RC beams to resist higher loads while maintaining structural integrity. However, this application precludes the beams' ability to exhibit significant ductility and, in turn, imposes a common failure mode known as premature de-bonding. Premature de-bonding of externally bonded FRP results in the lack of fully utilizing the strength of FRP while demonstrating immediate failure. Therefore, several anchorage techniques were suggested to delay or eliminate de-bonding in order to fully utilize the strength of externally bonded materials.

This paper aims at investigating the effectiveness of mechanically fastening and adhesively bonding Aluminum Alloy (AA) plates to RC beams by measuring their structural enhancements, in terms of stiffness and ductility. Three RC beams were designed and prepared in which one was left un-strengthened as a control beam, one was only adhesively bonded with an AA plate (CBE), and the last beam has AA plate that are mechanically fastened at its ends and adhesively bonded along its length. The specimens were tested under monotonic loading using displacement control mode. As a result, the beam with bonded AA plate showed a 32% increase in its load capacity and 45% increase in deflection compared to the control beam. This beam failed immediately by de-bonding of the AA plate. Whereas the bonded and mechanically fastened AA plate showed a 24% increase in its load capacity and 84% increase in deflection compared to the control beam. This beam failed progressively by means of intermediate de-bonding. It has been concluded that the combination of bolting and bonding, as an alternative anchorage technique, significantly increases the ductility in strengthened specimens while result in slight reduction in capacity. Furthermore, it reduces the de-bonding length of the AA plate as clearly depicted in the failure mode. Based on this promising result, further investigation is warranted to study the effect of different mechanical anchorage systems on the strength and ductility of beams strengthened with externally bonded AA plates.

Use of Aluminum Alloy Plates as Externally Bonded Shear Reinforcement for R/C Beams

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Abstract

Fiber Reinforced Polymers (FRP) and steel had proven to be very effective as externally bonded shear strengthening materials However, they both have their shortcomings. Recently developed high strength Aluminum Alloy (AA) plates possess desirable characteristics that may overcome some of the shortcomings of FRP and steel.

The aim of this paper is to study the behavior of Reinforced Concrete (RC) beams strengthened with externally bonded AA plates as shear reinforcement. Three RC beams were designed to fail in shear and two of them were strengthened with externally bonded AA plates that were oriented at 90^o and at 45^o. The beams were tested under four-point bending until failure while magnitudes of loads and mid-span deflections were recorded. The results of the tested beams showed an increase in the load carrying capacity of up to 38% compared to the capacity of un-strengthened control beam. All beams failed in shear with diagonal shear cracks followed by de-lamination/de-bonding of AA plates near the support and near the applied load. This study demonstrated that AA plates can be used as externally bonded material to enhance the shear capacity of RC beams, however, further investigation is needed to further validate these results.

Numerical model for the stress field ahead of a crack in elastoplastic regime

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Abstract Damage-tolerant designs admit the pre-existence of defects and small cracks, which lead to stress redistribution in structural components. The accurate knowledge of the stress field in parts under these conditions is important for damage accumulation analysis and residual life prediction. In this work, a numerical model via finite elements is proposed to determine the stress field ahead of crack tips in a plate under cyclic loading and elastoplastic regime. The analyzed center-cracked plate simulates a M(T) specimen made of 6005-T6 extruded aluminum alloy. From the triple symmetry condition, one eighth of the plate has been discretized with tetrahedral solid finite elements of quadratic order (Figure 1a). The refinement of the mesh has been concentrated around the crack tip region. The cyclic stress-strain curve of the material has been experimentally obtained by strain-controlled fatigue tests. With this curve, elastic and plastic parameters have been determined, considering elastoplastic material with isotropic hardening governed by Swift's law. Such a model differs from most usual stress analyzes in components with cracks, in which the possibility of hardening is not considered. It is important to emphasize that the law of nonlinear hardening adopted in this work does not allow the analytical solution of the present mechanical problem. Cyclic loading with ratios R = 0 and R = -1 has been applied from an initial crack of 11 mm in length. The crack growth was imposed by means of a simplified node release scheme. For each increment of 0.2 mm, stress fields and equivalent plastic strain have been determined for loading and unloading. Figure 1b shows the equivalent stress curves obtained at the maximum load for crack lengths of 11, 13 and 15 mm. The obtained numerical results justify the experimental data found for crack propagation in the same load ratios.

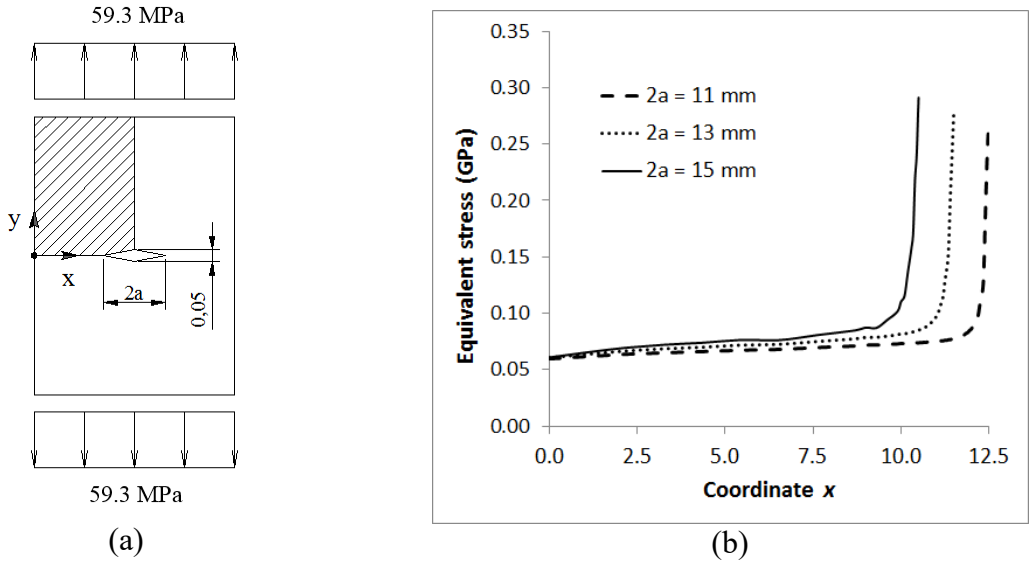

Figure 1 - *Boundary problem definition (a) and equivalent stress curves for three distinct crack sizes at peak load (b).*

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Continuous Monitoring and Evaluation of Railway Tracks: Proof of Concept

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Abstract: Railway track maintenance is a crucial aspect for the management of this type of transportation infrastructure regarding the technical and economic performance of the system. Track condition evaluation is usually carried out through labor-intensive visual inspection campaigns or with dedicated track inspection vehicles endowed with onboard vision systems. However, both techniques do not provide useful information on the causes that lead to track performance degradation and thus, maintenance actions tend to be more corrective and less preventive.

A R&D Project was recently completed in Portugal that aimed at designing, developing and demonstrating the applicability of an innovative and integrated approach to assess the performance and condition of railway tracks. A system prototype was developed and installed on board of a self-propelled railway maintenance vehicle. The system is designed to continuously evaluate the vertical stiffness of the track and to detect disturbances on the wheel and rail dynamic contact interactions. The system is also able to post-process the acquired data taking into account structural aspects of the track.

Following the work described in another paper submitted to ICSI 2019, this paper presents the methodology used in this project to process the acquired data and determine the relevant structural railway track parameters, such as railway track vertical stiffness, some geometrical properties of the rails and characteristic resonance frequencies of the vehicle-rail dynamic interaction. It also presents the results obtained from the first test using the prototype on a railway track under regular operation. For this purpose, a section of the track was instrumented with additional on-site equipment to provide data for further system assessment and validation. The instrumented section comprised part of a bridge over Ribeira de São Martinho and the adjacent transition zone, near Alcácer do Sal, in Portugal. The data obtained from this proof of concept test, together with the results gathered from previous phases of this project, suggest that the proposed approach is adequate in this context.

a) b)

Figure 1 - *Aspects of proof of concept test: a) overall view of the instrumented rail track section; b) passage of the* vehicle *over the instrumented section*

,Microstructure evolution and creep strength of new-generation ODS alloys with a high volume fraction of nanooxides

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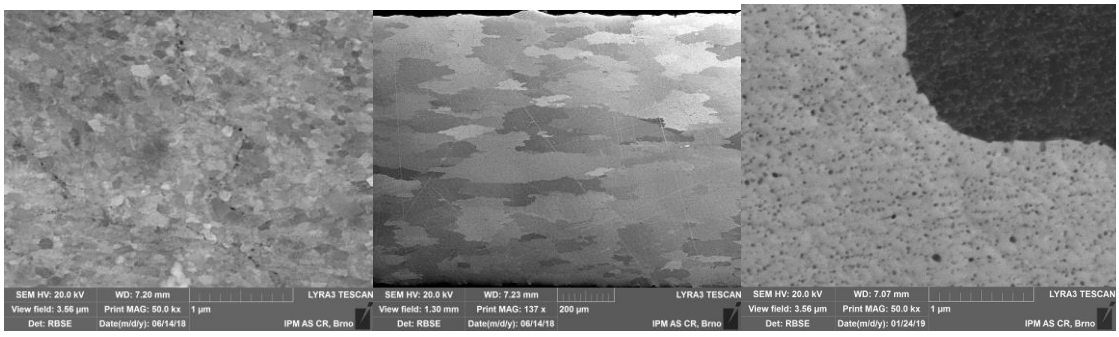
Abstract The creep resistant Fe-based ODS alloys with a significantly high amount of dispersed oxide precipitates have been investigated. Two Fe-Al-Cr-Mo-Y_2O_3 systems with different chemical composition strengthened by yttrium nanooxides have been prepared by mechanical alloying of powders and consolidation by hot rolling leading to ultrafine grained microstructure due to dynamic recrystallization (Fig. 1a). The thermal stability of the precipitates, effects of the processing on the microstructure (grain and precipitate size) and mechanical properties at high temperatures have been evaluated. It has been found that the rolling temperature has a significant effect on the static recrystallization process during the subsequent heat treatment and on the resulting grain size of the alloys (Fig. 1b) and does not affect the size of nanooxides and their dispersion (Fig. 1c). Tensile tests performed at a low constant rate of 10^{-6} s^{-1} allow a quick estimate of the creep strength and helps to a quick identification of optimum processing conditions. It was found that the mechanism of the fracture is changing from trans-granular to inter-granular between 600 and 800 °C which leads to a significant drop of ductility. The set of mechanical tests has been completed also for 1100 °C indicating a rather high applicability potential of the investigated system.



a) b) c)

Figure 1 *- Fe-17Cr-7Al-4Y_2O_3 ODS alloy a) after consolidation by hot rolling, b) coarse grained microstructure and c) dispersion of nano-oxides in adjacent coarse grains after static recrystallization.*

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Failure Mechanisms in High-Strength Eutectoid and Duplex Stainless Steel Wires Subjected to Tensile and Transverse Loads

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Abstract: Multi-wire strands are the most common resistant component of structural tendons used in a wide range of civil engineering applications. The tendons are designed to withstand high tensile loads, but they can also be subjected to permanent or accidental transverse loads that increase the contact forces between the wires and thus alter their tensile behavior.

This paper presents a comparative experimental analysis concerning the tensile bearing capacity of two classes of high-strength steel wires subjected this peculiar type of biaxial loading. The first one, made from eutectoid steel is commonly used today for prestressing strands fabrication and the second, made from duplex stainless, is a potential candidate for replacing it due to its higher durability. It resulted that the wires do not differ in the empirical criterion of fracture found to predict their tensile bearing capacity as a function of the applied transverse load. Figure 1 shows their similitude in the macroscopic failure mechanism comes from the local biaxiality of the stress state and from the microstructural alteration induced by the locally applied transverse load. However, the pearlitic nature of the eutectoid steel and the bi-phasic structure of the duplex stainless steel are the root cause of detected qualitative differences. The failure originates in an inclined slip band along which plastic instability occurs before fracture propagates. This band arises from the alignment and concentration of microcracks formed in the microstructural layers forced to gradually elongate and bend because of their proximity to the locally applied load.

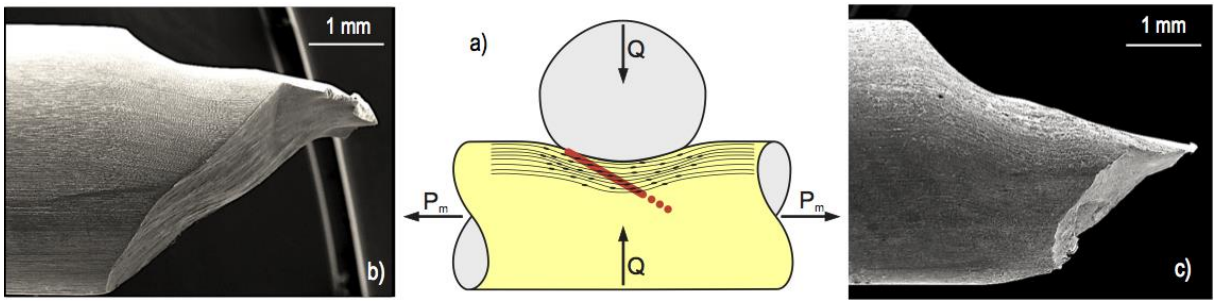

Figure 1. *a) Sketch of the test showing the inclined failure origin from microcracks alignment; Macroscopic views of failure: b) Eutectoid steel wire; c) Duplex stainless steel wire.*

,Environmentally-Assisted Cracking of Type 316L Austenitic Stainless Steel in Low Pressure Hydrogen Steam Environments

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Abstract Environmentally assisted cracking (EAC) is the dominant issue in determining the reliability of most commercial equipment and applications which are controlled by the interactions between structural materials, cooling environments and operating stresses. Hydrogen gas produces rapid growth of EAC in high strength steels, and this EAC initiates on surfaces which are absolutely smooth and requires no previous defects such as pits, intergranular penetrations or mechanical defects. The 300 series Austenitic Stainless Steels (ASS) are widely used in the nuclear industry due to their reliable long-term performance in high-temperature water. The EAC degradation can be developed during 20-30 years of operation conditions and it can be studied using acceleration testing in laboratory.

In the paper, the EAC tests have been accelerated by applying three factors: strain rate, steam environment and by increasing the temperature. Dominant acceleration via a Constant Extension Rate Test (CERT) has been employed. Moreover, tapered-shape specimens are used, which allows us to examine a range of stresses and strains simultaneously on one specimen. Flat tapered specimens with a thickness of 3 mm, width from 4 mm in the narrowest area to 6.4 mm in the widest one, and a gauge length of 26 mm were cut using electrical discharge machining (EDM) with the longer side parallel to the rolling direction of the plate. The parallel flat surfaces of the specimens were subjected to different surface finishes: one was manually ground to 500-grit in the direction parallel to the load axis, and the other one was polished using 1 μm diamond paste.

A low pressure superheated hydrogen steam system has been used to accelerate the oxidation kinetics while keeping the electrochemical conditions similar to those of the primary water in a pressurized water reactor. The cell was installed on an electromechanical creep testing machine Kappa SS-CF with a load capacity of up to 100 kN. Using a coiled heat exchanger the mixture 94% Ar + 6% H_2 gas with steam can be heated up to 480 °C. The air-leak chamber has a free level at a height of approximately 1 metre by which it keeps hydrostatically internal overpressure of approximately 0.1 bar.

Tests were performed on flat tapered specimens made from Type 316L austenitic stainless steel with a test rates of 2×10^{-6} and 2×10^{-8} ms^{-1} - at room temperature and at an elevated temperature of 350 °C and as a more oxidizing environment was chosen $R = 1/6$, on the contrary as a more reducing environment was chosen $R = 6$, where parameter R represents the ratio between the oxygen partial pressure at the Ni/NiO transition and the oxygen partial pressure. More oxidizing environment with $R = 1/6$ corresponds to a water flow rate of 2.22 mL/min, a

gas , mixture of 50 cc/min, a steam-to-H_2 ratio of 983 and an oxygen partial pressure of 2.48×10^{-30} atm. On the contrary as a more reducing environment was chosen R = 6 which corresponds to a water flow rate of 0.37 mL/min, a gas mixture of 50 cc/min, a steam-to-H_2 ratio of 164 and an oxygen partial pressure of 6.90×10^{-32} atm. Ultrahigh purity water with a conductivity of 0.055 μmS/cm was used. Different expositions (1 day and 5 days) before testing are consulted using post-test evaluation by scanning electron microscopy.

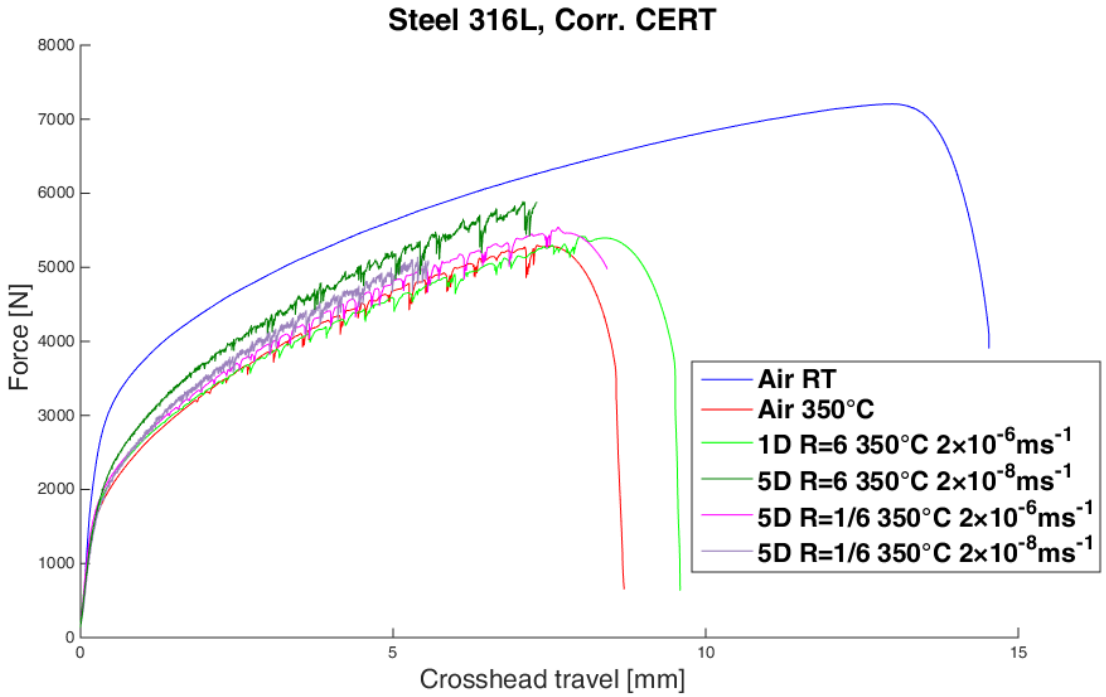

Figure 1 - *Measured curves of the CERT loading for samples exposed to a specific environment.*

Figure 1 shows the complete results of the tests where each curve corresponds to one sample exposed to a specific environment. To correctly interpret the results, it was necessary to perform tests without a sample at room and elevated temperature. These correction curves have been subtracted from the curves with the specimens because the correction curves represent the resistance of the spring bellows. All specimens failed by ductile fracture with extensive plastic deformation. Post-test evaluation showed that the flat surfaces were clean, practically without any oxide particles. The polished and ground surfaces behaved similarly. The SEM observation of the fracture shows typical ductile fracture dimples. It proved that a one-day exposure is likely insufficient for the material to be affected by the environments. Sporadic oxide particles of various sizes were observed at the surface for 5 days expositions. Plastic deformation of varying extents appeared in slip bands emerging from the surface. EAC cracks with the characteristic fracture mode and the orientation perpendicular to the loading were not observed.

Acknowledgements This work has been undertaken within the SUSEN Project (established in the framework of the European Regional Development Fund (ERDF) in project CZ.1.05/2.1.00/03.0108 and of the European Strategy Forum on Research Infrastructures (ESFRI) in the project CZ.02.1.01/0.0/0.0/15_008/0000293, which is financially supported by the Ministry of Education, Youth and Sports - project LM2015093 Infrastructure SUSEN. The support of Horizon 2020 MEACTOS GA No. 755151 is also acknowledged.

, Fracture toughness and Small Punch Test: review of methodologies and new proposal

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Abstract After more than 30 years of development, the Small punch has become a very popular test, with a new standard expected within a few months. The reduced dimensions of the test specimens, its simplicity and the high amount of information obtained from it, make the Small punch test one of the most promising alternative test techniques for mechanical characterization of metals. Tensile or creep properties and even fracture toughness are some of the characteristic values of the mechanical behavior of metals that can be estimating using the Small Punch Test.

This paper presents a review of some exisisting methods for obtaining fracture troughness from Small Punch Test together with the proposal of new methodology for the estimation of fracture toughness using Small Punch tests. The proposal is divided into the following steps: 1) measurement of the thickness of the specimen in the fracture region by destructive means or alternatively by CT (Computerized Axial Tomography, Figure 1), 2) determination of the fracture equivalent strain from the thickness measured in the previous stage 3) correlation between the fracture equivalent strain and fracture toughness, expressed in terms of CTOD. The main innovative aspect of this methodology with respect to existing proposals is the use of CTOD instead of J in the final correlation, which on the one hand is physically justified (both are deformation-based parameters) and on the other gives the method a higher reliability level.

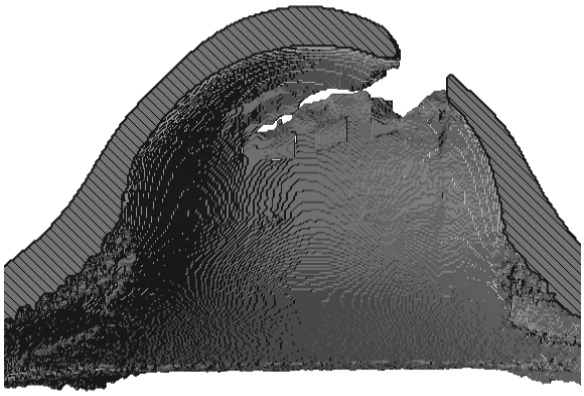

***Figure 1** – thickness measurement at fracture in Small Punch Test using CT.*

,The study of plastic deformation at fatigue crack tip during biaxial loading

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The origin and initial development of fatigue cracks occur under the action of the maximum tangential stress, which is less than the mode one and it is achieved at an early stage of the formation of a fatigue crack. It was experimentally shown that the crack resistance of steel is reduced when a shear loading component is introduced, which cannot be ignored when assessing the performance of structural elements under mixed loading conditions.These processes lead to irreversible deformation and failure that is accompanied by energy accumulation and dissipation. Theoretical and experimental investigation of thermodynamics of crack propagation process is one of the key issues in fracture mechanics.

A number of experimental and theoretical studies were devoted to the study of the features of fatigue cracks propagation, which are based on the assumption that, from a physical point of view, the determining factor for the process of crack propagation is the energy balance at its top. To calculate the energy balance, it is necessary to know the deformation energy and the dissipated energy. Today, for their determination, the method of infrared thermography, the method of correlation of digital images and the method of thermal stress analysis are used. This work is aimed at measuring the strain field at the fatigue crack tip under biaxial loading for subsequent analysis of the strain energy.

Experimental study of strain field at the fatigue crack tip was carried out on the plane specimens of stainless steel AISI 304 with a thick of 3 mm. The specimens were weakened by central notch to initiate fatigue crack. To measure the deformation the method of digital image correlation was used based on strainmaster system. There used macro lens and spatial resolution of 3 um was obtained. The biaxial tests with different biaxial parameter (0, 0.5, 1) were carried out with biaxial testing machine Biss BI-00-502.

The shape and size of plastic area near the fatigue crack tip was obtained. These data will allow verification of models describing the behavior of fatigue cracks. The result of numerical simulation are coresponded with experimental. There is decrease of plastic zone with increase of biaxial coefficient. This can be caused by an increase in the influence of the shear strain component with increasing side load.

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Continuous Monitoring and Evaluation of Railway Tracks: System Description and Assessment

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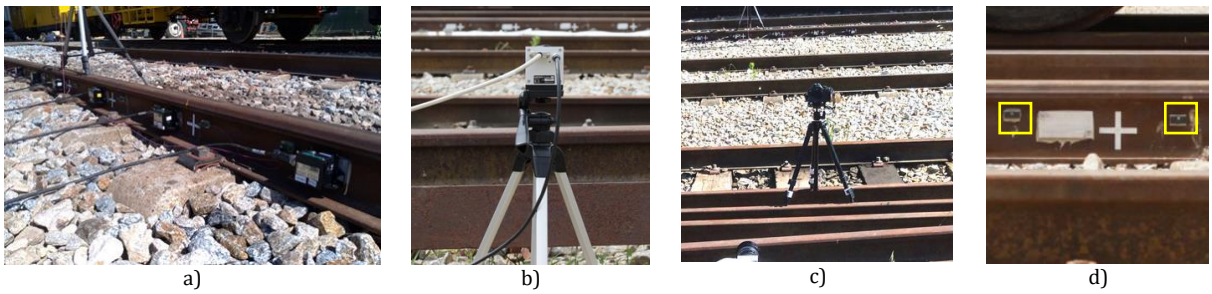
Abstract: Railway track maintenance is a crucial aspect of railway infrastructure management in terms of technical and economic performance of the transportation system. The planning of maintenance actions is commonly based on observation of infrastructure condition. Track condition evaluation is usually carried out with manual visual inspection campaigns or with dedicated track inspection vehicles endowed with onboard vision systems. This traditional approach to track condition evaluation is generally considered adequate. However, it does not provide useful information on the causes that lead to track performance reduction and thus, maintenance actions tend to be more corrective and less preventive.

A R&D Project was completed in Portugal that aimed at designing, developing and demonstrating the applicability of an innovative and integrated approach to assess the performance and condition of railway tracks. This approach is also expected to contribute to identify the specific causes of some track performance degradation, namely those that are related to the characteristics of the layers and the geomaterials that compose the substructure of the track. A system prototype was developed and installed on board of a self-propelled railway maintenance vehicle. The system is designed to continuously evaluate the vertical stiffness of the track and to detect disturbances on the dynamic contact interface between the wheelsets and the rails, some of which can be related to defects on the tracks. The system is also able to post-process the acquired data taking into account structural aspects of the track.

This paper includes an overall system description of the prototype implemented based on the discussed approach and the first experimental tests performed with said prototype, regarding the system assessment. These tests were performed on a railway track, adjacent to a maintenance yard. The track was instrumented with additional on-site equipment to serve as reference for the prototype's assessment. The data obtained from the preliminary tests suggest that the proposed approach is adequate in this context.



a) b) c) d)

Figure 1 - *Aspects of pilot test's instrumentation: a) accelerometers; b) industrial type video camera; c) high resolution camera; d) passive (cross) and active (LED) targets*

Effect of temperature and fatigue loading condition on shear lap strength of an epoxy adhesive reinforced with micro cork particles

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Abstract

The application of adhesively bonded joints in the automotive industry has increased significantly mainly driven by the need for lighter vehicles, improved fuel economy and reduced emissions [1]. Epoxy resins are one of the most used structural adhesives, due to their versatility as well as their mechanical, thermal and chemical resistance and can be modified so that their properties can vary from very stiff and strong to flexible and ductile by inclusion of a second phase. Several materials can be used to modify the epoxy mechanical properties, so that a uniform stress distribution along the overlap can be obtained. Natural materials, such cork, can modify epoxy adhesives. There is also pressure on industries to use these type of materials, in order to reduce their carbon footprint. Cork as an interesting cell structure that can be applied to reinforce a brittle adhesive. Cork is able to improve the adhesive mechanical properties without detrimental effects on the curing process and on the hydrothermal degradation of the adhesive [2-4].

The present study deals with the effects of temperature and cyclic loading condition on strength of single lap adhesive joints enhanced with different amounts of micro cork particles. To achieve this, different joints with various overlap lengths were manufactured and tested. The joints were tested at two different temperatures (-20ºC and 75ºC) in quasi-static conditions. Results of high temperature (75ºC) show that the joints tensile strength decreases with the amount of cork particles. For low temperature (-20ºC), the strength of the joint with 1 vol% of cork increased however, higher amount of cork lead to reduction of the joint strength. To investigate the influence of cork particles on fatigue endurance of the joints, they were tested

at room temperature under sinusoidal cyclic loading. Based on the experimental data it was found that the cork particles could significantly improve the fatigue life of adhesive joints (up to 4.6 times). Micro failure analysis of the tested joints was also performed using the scanning electron microscope (SEM) technique.

Acknowledgements

Financial support by Foundation for Science and Technology and Balcão2020 (POCI-01-0145-FEDER-028035) are greatly acknowledged.

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, Experimental and finite element analysis of progressive failure in friction stir welded AA6061-AA7075 joints

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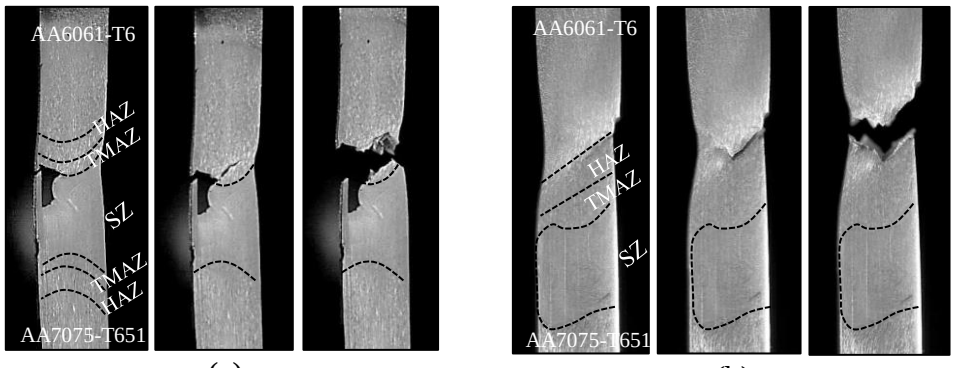
Abstract Friction stir welding (FSW) is widely used for joining of aluminum and other lightweight alloys without much distortion, and residual stresses. However, selection of tool pin profiles, process parameters are important to avoid formation of defects like tunneling, cracks, voids, etc. as these defects can act as failure initiation site. In the present study, an in-situ analysis of crack initiation and propagation during tensile loading was captured using high speed camera for dissimilar FSW joints between AA6061-T6 and AA7075-T651 prepared with plain cylindrical (CYL) and threaded with three intermittent flat faces (TIF) tool pin. Joint failures were further predicted by finite element (FE) analysis incorporating ductile damage criteria to unveil the failure mechanism. To create a realistic FE model both geometrically and mechanically, the FE model was segmented into different regions - stir zone (SZ), thermo-mechanically affected zone (TMAZ), heat affected zone (HAZ) and base metal (BM). The shape and size of these zones were modeled as per dimensions measured. In addition, tunnel/void region (observed in joint with cylindrical tool pin) was also incorporated in FE model. In order to assign the material properties, tensile testing of both the base materials were performed as well as tensile sample was cut from the weld stir zone (along the weld seam) and tested. The fracture strain ($\varepsilon_p = \sqrt{2/3 \times \{{\varepsilon_t}^2 + {\varepsilon_w}^2 + [-(\varepsilon_t + \varepsilon_w)]^2\}}$) was also calculated by measuring the fracture sample dimensions in necking region and calculating the strains in thickness (ε_t) and width (ε_w) direction. Since, the TMAZ and HAZ are very narrow, individual tensile samples were not available from this regions thus based on the hardness values at these regions the material properties were obtained. For the base metals on advancing (AA6061) and retreating (AA7075) side, the relationship between ultimate tensile strength (σ_u) and yield strength (σ_y) was established in terms of Vickers hardness (H_v) in the form: $\sigma_u \ or \ \sigma_y = a + (b \times H_v)$. For joints obtained with CYL tool the crack initiated from the vicinity of tunnel region however propagated through the boundary of SZ and TMAZ (Figure 1(a)). FE results also indicate that the stresses and plastic equivalent strain were confined near tunnel region which act as crack initiation site. For joints obtained with TIF tool where no tunnel defect was observed in SZ, the sample failed from the region adjoining of BM and HAZ on the advancing side (Figure 1(b)). To study notch sensitivity, FE analysis and experiment were carried out for notched tensile sample creating notch at weld SZ.



(a) (b)

***Figure 1** – Progressive failure captured using in-situ technique for joint prepared with (a) CYL tool (SZ having tunnel defect) and (b) TIF tool (SZ having no defect)*

, Fracture mechanical behavior of different low alloyed titanium thin sheets welded by Yb:YAG fibre laser for T-ducts in bleed air systems

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Abstract A bleed air system is a network consisting of ducts, joints, valves, controllers and welded components to extract pressurized air from the compressors of main aircraft engines as well as auxiliary power units [1, 2]. This bleed air is transported to different sectors of an aircraft and includes essential functions such as pressurization of passenger cabins, air conditioning, engine startup, de-icing of engines and wings as well as pressurization of hydraulic reservoirs and water tanks [1]. Especially, bleed air having a temperature of 200 °C until 250 ° and a pressure of 2.8 bar must be conditioned to achieve breathable air and bearable temperatures within the passenger cabins [1]. The components of a bleed air systems are subjected to cyclic pressurization and heating cycles [1]. Damages in air-conditioning systems and bleed air systems make up approximately 29 % of failure cases in older aircrafts [3]. Titanium Grade 2 or titanium Grade 3 are preferred light-weight materials for the production of curved and straight ducts used in bleed air systems [4, 5]. Unalloyed titanium combines high resistance against corrosion and oxidation, moderate strength, fatigue strength, elevated strength-to-weight ratio and good weldability [2]. Pneumatic ducts made of titanium have wall strengths of 0.5 mm until 1.2 mm and diameter of 100 mm until 120 mm.The PAW or TIG joining technology are applied for welding of titanium ducts [2]. However, failures of titanium ducts in connection to cracking adjacent to welds have been reported in literature [2, 4]. The main cause of damage is the interaction of embrittlement, tensile residual stresses and cyclic load composed of vibrations during in-flight, cyclic pressurization and heating cycles [4]. The embrittlement was attributed to the heat input during the welding and subsequent low cooling leading to formation of coarse grains in heat-affected zone as well as absorption of ambient air due to instable protection gas atmosphere [4]. Laser beam welding is a suitable approach to overcome the disadvantages caused by application of PAW or TIG joining technology.
In the frame of TiB-Air project funded by the German Federal Minsitry for Economic Affairs and Energy (BMWi) the mechanical properties of Yb:YAG fibre laser welded titanium sheets with a thickness of 0.9 mm such as KS1.2ASN, titanium Ti XT and titanium Grade 4 regarding fracture toughness, tensile behavior, fatigue strength and fatigue crack propagation have been investgated to obtain a data base for admission of KS1.2ASN and titanium Ti XT used for the production of pneumatic ducts in bleed air systems. Titanium Grade 4 was used as reference materials. It will be shown that KS1.2ASN, Ti XT and titanium Grade 4 can be considered as alternative to the commonly used unalloyed titanium grade 2 or titanium grade 3.

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, Towards a Generalized Methodology for Structural Integrity Calculations of Large-Scale Pressure Vessels

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Keywords: Structural Integrity Calculations, Large-Scale Pressure Vessels, Methodology, Fracture Mechanics

Abstract: Structural Integrity calculations are critical parts of the design, certification procedures and safety analyses for the demonstration of design life, and for the assessments of the technical allowable lifetime of large-scale pressure vessels, used in electric power generation industry. The significance of these calculations is being nowadays even more increasing, when the feasibility of long-term operation (i.e. operation between 50 and 80 years) of working equipments has become an increasingly relevant issue. Stuctural Integrity calculation methodologies are nowadays directed by international standards and guides, and supported by newer results of applied research, technical development and best engineering practices. Although application of the latest achievements of experimental methods (e.g. destructive, nondestructive material testing methods) and information technology (data acquisition systems, high performance computing) highly contributed to improving the accuracy of safety evaluation of large-scale pressure vessels, predictive power of the standard analysis methodology has not improved significantly (e.g. the load history effects are poorly described by these calculations). From theoretical point of view, these methodologies are mainly based on the widespread 'traditional' thermal-stress approach –which is essentially based on the weakly coupled model of classical thermomechanics– and fracture mechanics. During fracture mechanics calculations, global approaches of fracture play a prominent role. Beyond that, their ability to predict vessel's behavior after long-term operation is largely limited by the strong dependence of the analysis methodology on the empirical models correlated to the behavior of structural materials and their changes during material ageing.

There are various attempts, to overcome the limitations of current Structural Integrity calculation methodologies of large-scale pressure vessels, but these days, the results of different research and development activities do not form a coherent system yet. Currently, a research is being conducted in MTA EK with the aims, to come a better understanding of the reasons, why the results of the calculations on different newer models differ significantly in many cases, and to develop a new, generalized methodology for future Structural Integrity calculations of large-scale pressure vessels. One of the first results of the research was the conceptual model of Structural Integrity. This conceptual model describes –at an abstract level– the general properties/characteristics of different Structural Integrity calculation methodologies, regardless of the details of the theoretical and computational approaches used in different models. According to the conceptual model, there are four key aspects, which are inherently present in any Structural Integrity problem: (1) theoretical aspect; (2) analysis aspect; (3) experimental aspect; (4) information technology aspect. These key aspects form an integrated, more or less coherent system at engineering level, when the standard based Structural Integrity analysis methodology is used. The situation is more complex, when the question is about, how to include more general models of structural materials in the calculation methodology. In that case, reliability of the calculation methodology must be based on more general –physically sound– principles, than the standard analysis methodology. During the presentation, the conceptual model and its application in the ongoing development of the generalized methodology for Structural Integrity calculations of large-scale pressure vessels will be described in more detail.

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Static Elasticity Modulus Analysis of Coating Mortars

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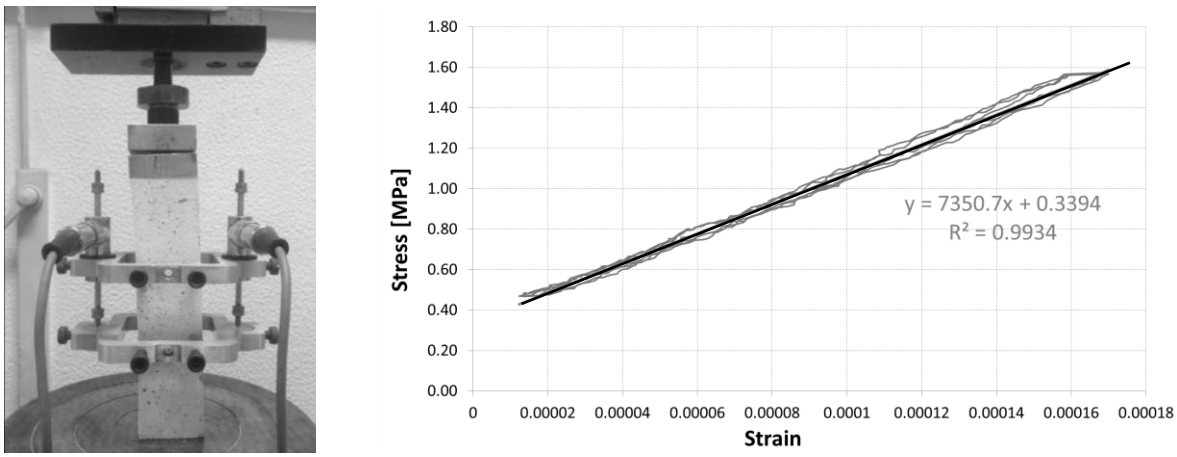
Abstract: Coating mortars should have the ability to deform, without critical failure, when subjected to loading actions, thermal cycles or shrinkage of the mortar itself. When the mortar cannot cope with these deformations, internal stresses arise in the coating. This can lead to cracking, which is one of the most frequent and damaging anomalies in building facades. To minimize this issue, knowledge of the coating mortar's modulus of elasticity (E) is essential during the design process, in order to achieve proper compatibility between the mortar and the underlying support structure regarding material deformability.

There are two methodologies to experimentally determine E for coating mortars: static experimental procedures and dynamic experimental procedures. For civil engineering applications, the results obtained from static procedures are usually more reliable than those obtained with dynamic procedures. There are several dynamic procedures available that can be used in this context, like the Resonance Frequency Method and the Ultrasound Method, but currently there are relatively few reliable static experimental procedures.

This paper presents the results obtained with an improved experimental procedure to determine the static E for mortars. These results contain data acquired with specimens made from multiple mineral binders. The data collected so far with this experimental procedure give evidence to values well within the expectable range of static E values for cement and lime specimens.



a) *b)*

Figure 1 - *Static elasticity modulus test: a) instrumented specimen during a test and b) resulting stress-strain curve that gives 7,35 GPa of E for a hydraulic lime specimen*

, Correlation between steel initiation toughness and arrest toughness determined from small-scale mechanical testing.

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The ability of a material to arrest a fast-running brittle crack is vital in various industries such as offshore wind, oil and gas, and shipbuilding where cracks can initiate in regions of local stress and put lives at risk. Some modern steels show a high Charpy toughness, but low resistance to crack propagation – i.e. low crack arrest toughness [1,2]. In this work, the relationship between initiation and arrest toughness is investigated in five different steels, including S355 structural steel, X65 pipeline steel and two high strength reactor pressure vessel (RPV) steels.

Small scale mechanical testing was carried out to determine the material properties, which were correlated against the microstructural characteristics of the materials. The test program included instrumented Charpy, drop weight Pellini, fracture toughess, tensile testing, and microscopy. Nil ductility transition temperature (NDTT) is used as a measure of arrestibility. Initiation toughness showed the expected correlations with upper shelf Charpy and grain size measurements, however these did not correlate with the arrest toughness. The arrest toughness is better correlated against the T_{27J} temperature – i.e. the onset of the lower shelf. This relationship is valid even for steels where the NDTT lies on the upper shelf of the Charpy curve.

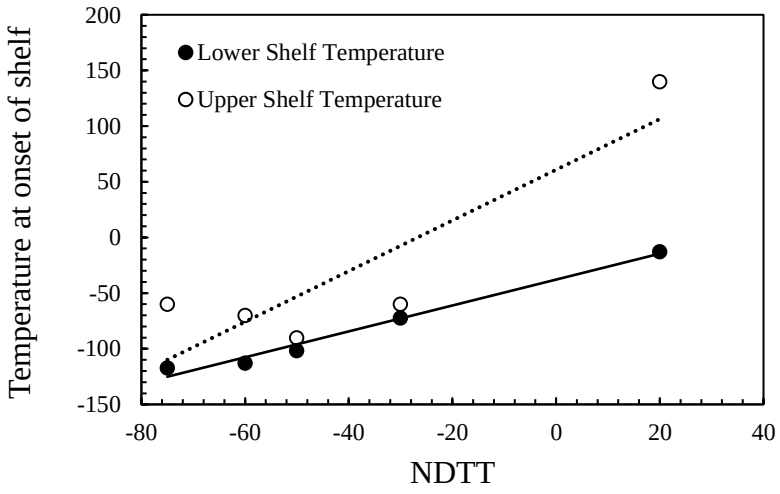

Figure 1 – *Correlation between lower and upper shelf Charpy temperature and NDTT*

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, Compatibility of fracture toughness results in the upper shelf region

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Abstract Fracture toughness has been used for decades nowadays for structure integrity assessment and it is important mechanical characteristic for new materials as well. In the upper shelf region, where stable fracture behavior is observed, concept of J-R curve is widely apply to determine fracture toughness parameter JIc defined by the intersection of the 0.2 mm offset construction line and the J-R curve according to ASTM E1820. Fracture mechanic methods have been well established in the community especially for standard sized specimens but as it was mainly developed for large structures assessment against the brittle failure, standardized specimens are of large size at present. In many cases, such as evaluation of additively manufactured products properties, residual life of in-service components, local properties of components, weld joint, etc., standard specimens are not possible to use due to size requirements. Therefore, small sized specimens are necessary to use for material characterization. Due to constraint effect, the results obtained from standard and small sized specimens may be different. In the current paper, fracture toughness properties are going to be investigated using different sized samples scaled from mini-Charpy or mini-CT specimens to the standard one. Based on experimental results from several structural metals like steels 34CrNiMo6 and 27NiCrMoV 15-6, a procedure leading to the comparable results from small to standard samples will be proposed. Usability of suggested procedure will be demonstrate on newly developed materials produced by AM technology.

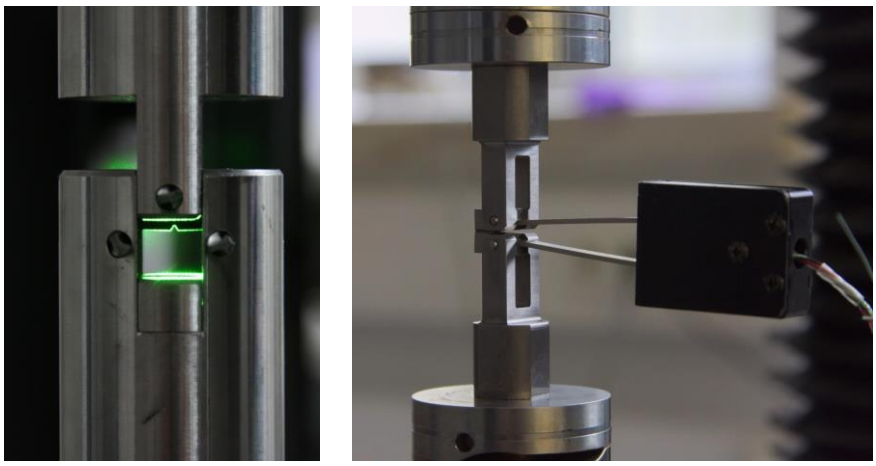

Figure 1 - *Testing setup for fracture toughness tests*

Investigation of the fatigue crack retardation caused by laser shock peening induced residual stresses using a multi-step simulation and experiments

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Laser Shock Peening (LSP) leads to a retardation of the Fatigue Crack Propagation (FCP) in metallic components by introducing high compressive residual stress fields. Besides the high value of compressive residual stresses, which can be close to the yield stress, these residual stress fields are characterized by a relatively high penetration depth compared to other methods such as shot peening. LSP uses short high-energy laser pulses to vaporize the surface material. The vaporized material is turned into plasma, whereby the plasma pressure causes a mechanical shock wave travelling through the material. A sacrificial layer, also referred to as ablative layer, can be used to produce high surface quality. After relaxation of the system, local plastic deformations resulting from the mechanical shock wave lead to the residual stress field. As the residual stresses need to satisfy the equilibrium, tensile residual stresses are always generated as well. Tensile residual stresses accelerate the FCP, so the introduced residual stress field must be known in detail to guarantee an efficient application of LSP.

In this work, a multi-step simulation strategy is applied and validated to predict the FCP in LSP-induced residual stress fields [1].The multi-step simulation consists of (i) an LSP process simulation [2] (ii) a transfer method of plastic strains from the LSP process model to an FCP model based on the eigenstrain method, (iii) the calculation of the residual stresses in the FCP model and the FCP simulation to predict the crack-driving stress intensity factors and the calculation of the FCP rate using FCP equations, particularly the NASGRO equation, Walker's equation and Paris' law. The multi-step simulation is validated using an `experimental simulation', where predicted crack-driving stress intensities are applied to an unpeened specimen. The `experimental simulation' agrees well with experiments using peened specimens and thus validates the predicted stress intensity factors. In addition fatigue crack retarding and accelerating mechanisms are shown and discussed.

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Vibration-based fault detection for flywheel condition monitoring

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Abstract Flywheels are one of the more promising energy storage devices for stabilizing the power quality of reusable energy, owing to their fast response time and high cycle lifetime. However, it can be catastrophic when they fail, because they store kinetic energy that can be released in a short amount of time. Data-driven monitoring techniques have been proposed to solve fault detection tasks in several types of rotation machinery with ball bearings. In contrast to traditional approaches using human-engineered features that require a high level of expertise, a data-driven approach requires no such prior knowledge. However, flywheels differ from typical rotation machinery because they use a magnetic or pivot bearing, and it is unclear whether a data-driven method can be used to detect a fault. Hence, the aim of the present study is to evaluate the effectiveness of a data-driven fault detection system for flywheels that use pivot bearings. A flywheel fault progresses in several stages. Initially, there is a loss of helium that is originally filled inside the flywheel. Subsequently, degeneration of the oil around the pivot can be confirmed before a final breakdown. However, directly detecting these signs is not easy. Therefore, we aim to construct a system that can detect each of the stages using vibration data that can be collected easily by attaching an accelerometer externally. Vibration data were collected for a flywheel running at three statuses: healthy, no helium, and oil degeneration (bad oil). The respective data for these conditions were collected for 107, 21, and 7.7 hours. Using the collected data, a convolutional neural network (CNN), one of the most successful data-driven methods, was trained to classify a given vibration data to the aforementioned three statuses. The CNN takes a feature extracted from the raw vibration data as an input, and outputs the posterior probability of each status. The feature extraction is achieved by applying a fast Fourier transform to the vibration data, and the system is evaluated by a five-fold cross-validation. The developed system yielded a high average accuracy (99.97%), and the confusion matrix of classifier outputs is shown in Table 1.

Table 1 – Confusion matrix of classifier's outputs.

input \ estimate	healthy	no helium	bad oil
healthy	99.97	0.03	0.00
no helium	0.04	99.95	0.01
bad oil	0.01	0.00	99.99

The result shows that it is possible to classify each state of the flywheel with high accuracy using a data-driven method. The result of this study is expected to improve the condition monitoring of flywheels at sites where expert knowledge is not sufficient, or at sites that are not easily accessible.

,Tensile strength and failure of dissimilar friction stir welded joints between 6061-T6 and 2014-T6 aluminum alloys

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Abstract Friction stir welding (FSW), a promising solid-state joining process, has gained significant importance to successfully join dissimilar metals and alloys. The friction between the non-consumable rotating tool and workpiece along with the adiabatic plastic deformation of the workpiece generates heat that softens the workpiece material however no melting takes place. The plasticized material flows around the tool pin, mixes and joint formation takes place primarily due to solid state diffusion. However, selection of tool pin profiles, process parameters are important to avoid formation of defects like tunneling, voids, etc. generally appears due to improper heat input, flow and/or mixing of materials. The present study focuses on successful joining between AA6061-T6 and AA2014-T6 alloys in order to achieve joints with minimum or no void and maximum tensile strength of the joints. Two different tool pin profiles i.e. threaded with three intermittent flat faces (TIF) and truncated square pyramidal shaped (front appearance of trapezoidal tapered) (TPZ) tool pin were selected. Dissimilar FSW of AA6061-AA2014 was carried out at combinations of tool rotational speed (660, 900, 1200 rpm) and weld traverse speed (36, 63, 98 mm/min). Transverse tensile samples were prepared and tested at Zwick/Roell Z050 tensile testing machine (capacity 50 kN) at cross head speed of 0.5 mm/min. Contact type extensometers of 25 mm gauge length were used to record yield strength (0.2% offset strain). Each test was repeated three times and macroscopic observations of failure of the joints were performed in addition to the fractographic studies using scanning electron microscope. Results revealed that for TIF tool pin, the maximum joint tensile strength was achieved at 1200 rpm tool rotational speed with 98 mm/min weld speed (as represented in Figure 1(a)). On contrary, with TPZ tool pin the maximum joint strength was recorded for joints prepared at 660 rpm tool rotation and 63 mm/min weld speed. On both cases, the tensile failure of the joints initiated and propagated at the advancing side (AA6061-T6) wherein failure in joint prepared with TIF tool pin took place through the interface of heat affected zone (HAZ) and base metal however, for the case of TPZ tool pin joint failure was observed at interface of stir zone (SZ) and thermo-mechanically affected zone (TMAZ). Detailed metallurgical characterization of different weld zones and fractographic studies were also performed.

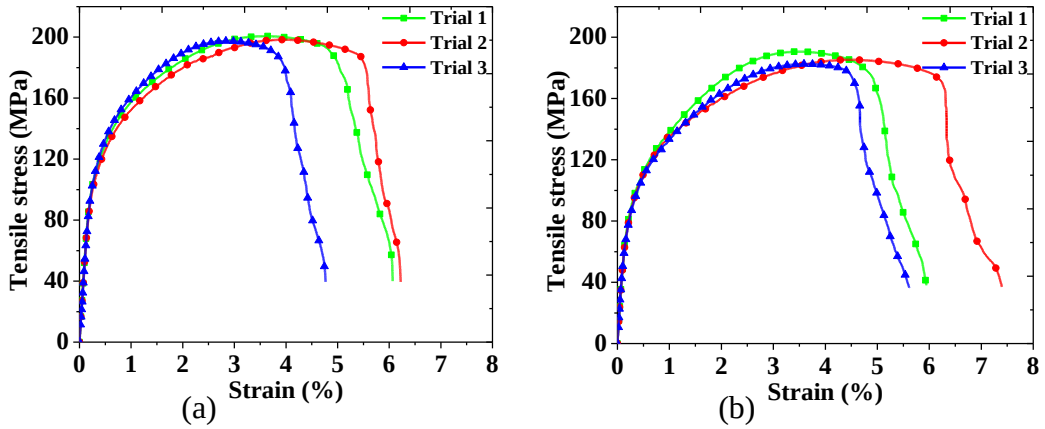

Figure 1 *–Representative tensile stress vs strain plots for AA6061-AA2014 FSW joints prepared with (a) TIF tool, 1200 rpm, 98 mm/min and (b) TPZ tool, 660 rpm, 63 mm/min*

, Fatigue tests of materials with the controlled energy parameter amplitude

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Abstract The paper presents a procedure of the fatigue energy characteristic determination with a controlled energy parameter W_a. This parameter can be an alternative for well-known stress (S-N) and strain (ε-N) fatigue curves of structural materials, as also obtained from the calculation of the energy curves. The work contains the results of fatigue tests carried out in accordance with the procedure shown in the paper.

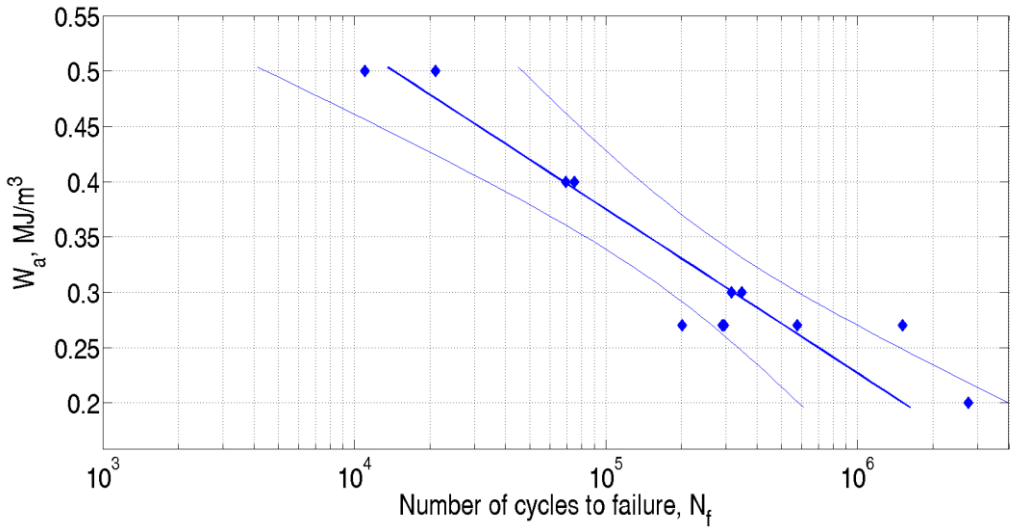

***Figure 1** – The fatigue energy characteristic of C45 steel*

Fig. 1 shows the energy performance of C45 steel obtained for tests with zero mean load (R = -1). This characteristic is fundamental to assess fatigue life for random or variable-amplitude loading.

, Austenitic cast iron resistant against the abrasive material degradation

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Abstract In producing processes there are components that are exposed to a high degree of abrasion. The paper is presenting the criteria for the selecting of chemical composition for white chromium cast iron that has the high abrasion resistance and increased fracture resistance. The results of experiments focused on the selection of the alloying element combination that can produce a predominantly austenitic matrix with the big portion of the carbide components are presented. The compositions of developed two types of chromium cast irons that have high resistance for fracture and abrasion in as-cast state are given. The base information on the producing method and on the service properties of these cast irons, which were successfully put in practice are presented

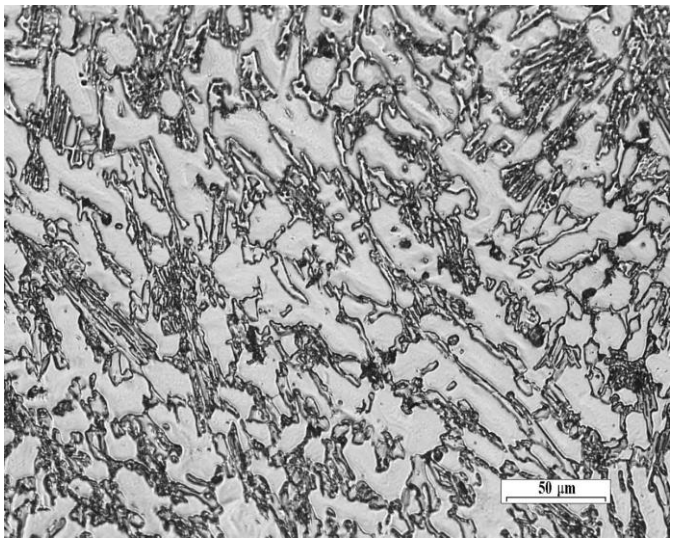

Figure 1 – *Microstructure of abrasive resistant austenitic iron*

, Degradation mechanisms in the operation of pressure pipelines

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Abstract Many non-standard situations (subsoil sliping, vibrations, ...) as well as degradation mechanisms of pipeline materials occur in the operation of pipelines. The article is devoted to mechanisms such as corrosion, brittleness and ageing of steels used in piping systems. Material ageing of steels is documented by the results of experimental measurements on samples of piping materials after multi-annual operation.

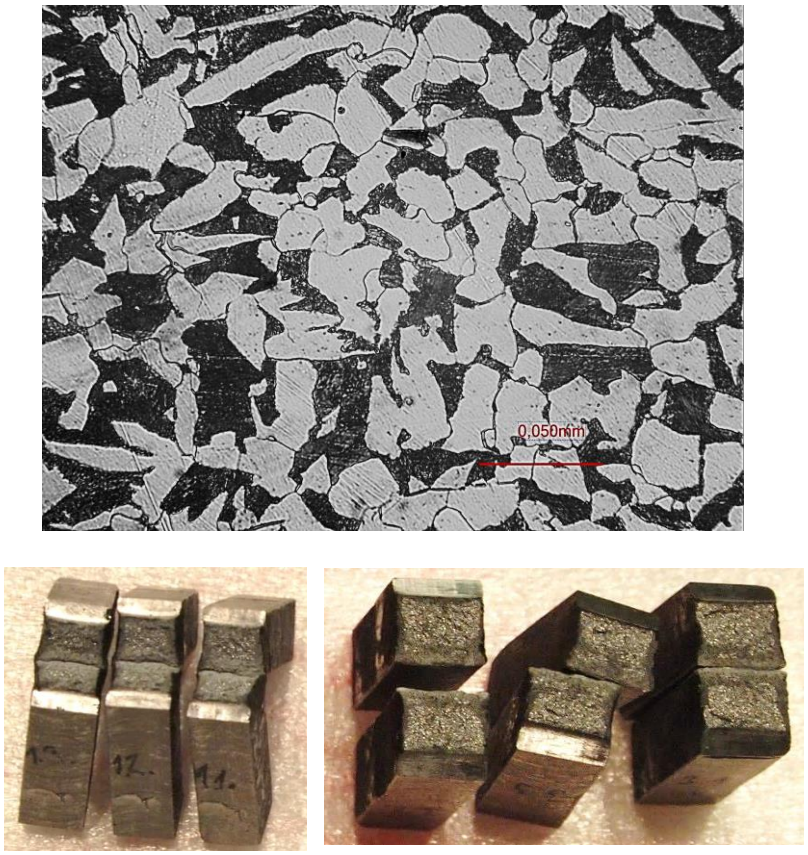

Figure 1 – *The ageing of pipe steel and its brittleness*

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Safety of pressure pipe operation with corrosive defect

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Abstract The criterion of pipeline operation safety presents the ratio between the burst and the operation pressure. Correctly set values of burst pressure in the pipelines are a distinct task only in case of ideal pipe, as for such a case, there exist an analytical solution. In the actual operation however, the burst pressure value is influenced by the floor status, pipe surface corrosion defects, and further aspects, which can hardly be quantified. The authors state in the article, that the utilization of semi-empiric relations from the standards DNV-RP-F101 or ASME B31G, can lead to biased results. Experimental measurements of burst pressures can quantify these biases. The methodology of destructive pressure calculation for pipeline with local weakness of wall thickness using the numerical models which are verified by direct measuring of those pressures is presented.

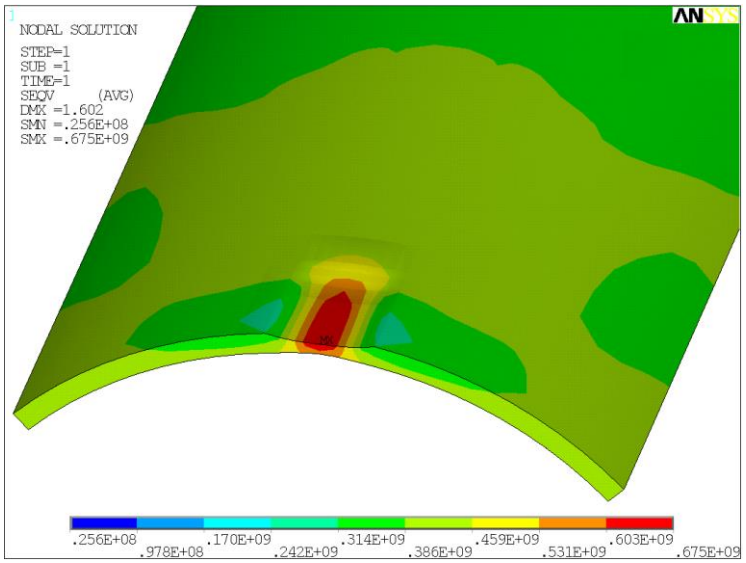

Figure 1 – *FEM-model of pipe with corrosion defect*

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Analysis of cracks propagated in a tee pipe fitting

C. Medrea[1],*, E. Pappa[1], D.G. Papageorgiou[1,2], C. Stergiou[1]

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Abstract A Greek Company generates electricity via combined cycle using natural gas. The air passes through the inlet to the compressor. The compressed air is mixed with the preheated fuel and then ignites; producing exhaust gases and makes the gas turbine blades spin. The turbine shaft drives this energy to a generator shaft, converting part of the spinning energy to electricity. Then, a steam generator uses the exhaust heat from the gas turbine as recovery energy, in order to create steam and deliver it to the steam turbine producing additional electricity. The steam is then condensed back to water and recycled. The condensation procedure is enhanced by using forced draft cooling towers (Fig.1a). The "U" shaped fan blade holders are frequently failed, disturbing the normal operation of the unit (Fig. 1b).

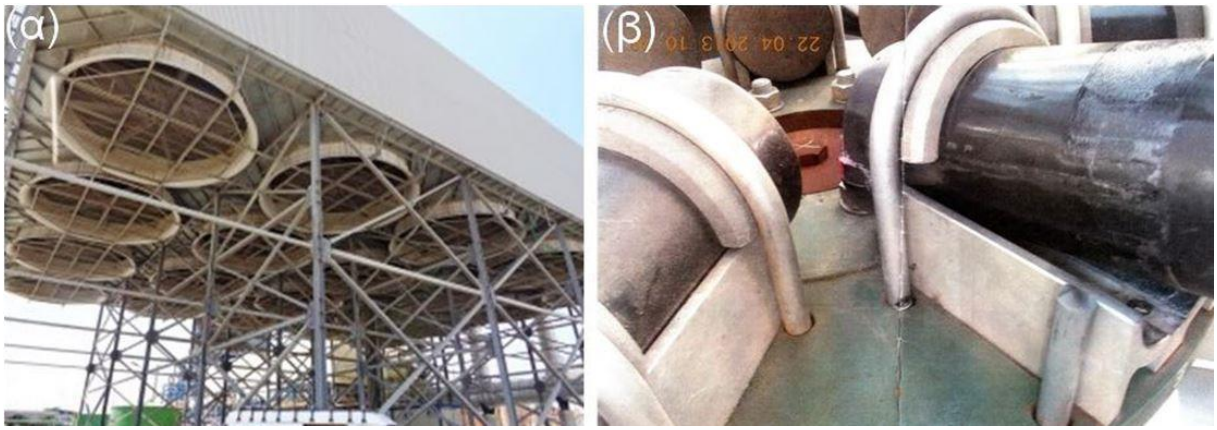

Figure 1 - *(a) General view of the turbines arrangement on cooling tower, (b) Fractured 'U' shaped fan blade holders (reversed image)..*

Three representative components were analyzed. The study includes historical data collection, macroscopic examination with neck eye and under stereoscope, hardness measurements and chemical analysis. Furthermore, light and scanning microscopy was performed as well as fractography of representative fracture surfaces. Conclusions regarding the failure mode and its main causes are presented and recommendations are provided in order to avoid similar problems in the future.

, **Microscopic examination of a fan blade supporting system premature fractured**

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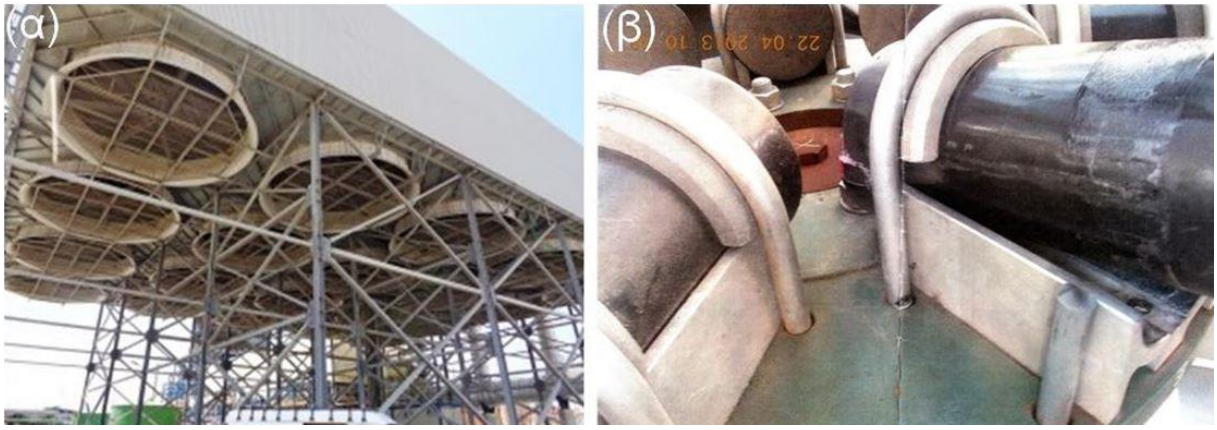

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, Plasticity induced crack closure distribution along crack front

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Plasticity induced crack closure (PICC) mechanism was first described by Elber [1] in 1970. Since that time, big progress has been done and fatigue crack closure has been studied both experimentally and numerically. Ability of accurate description of this phenomena because of its significant impact on the fatigue crack propagation rate is in the interest of scientific and engineering community. Performing finite element analysis of plasticity induced fatigue crack closure is highly non-linear problem due to the assumption of elastic-plastic material model together with required contact definition on crack faces. Several input parameters as well as chosen methods of crack closure estimation may affect results significantly and comparison with experimental observations is not always straightforward. Additionally, most of the numerical simulations studied PICC only using two-dimensional models.

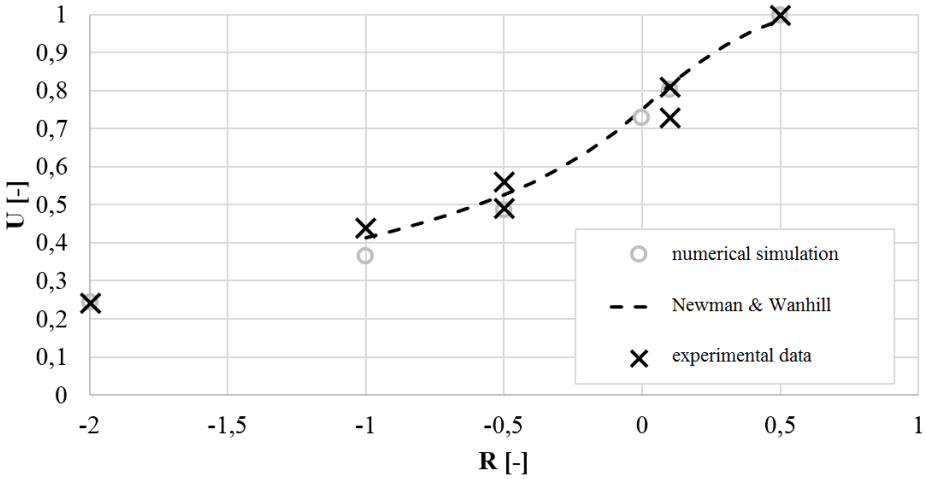

Figure 1 - *Numerical PICC determination for various load ratios compared to experimental data and Newman and Wanhill equations.*

Therefore, presented work is focused on numerical modelling of plasticity induced crack closure, using three-dimensional numerical model. Two dimensional FEM simulation was

compared first with experimental data [2] performed on middle tension (MT) specimens made from EA4T railway axle steel, see Fig.1. Based on this comparison best strategy for numerical modelling of plasticity induced crack closure was found. It has been observed that generally adopted suggestions as length of crack growth or number of substeps are not necessarily valid in general, but requires to be individually specified for different conditions. Based on this knowledge, three-dimensional model of the structure was prepared, see Fig.2.

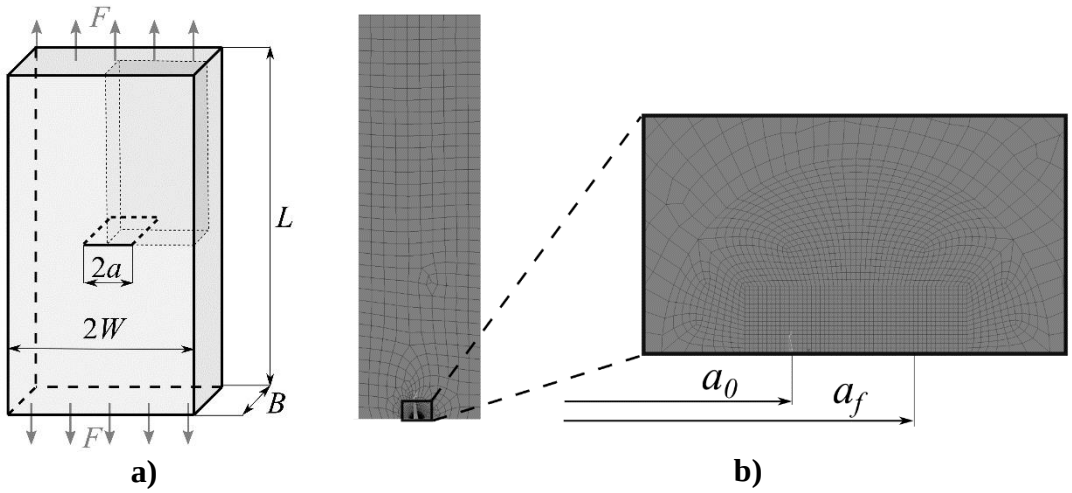

Figure 2 - *M(T) specimen (a) and FE model with detail of mapped mesh in the crack advancing area (area between a_0 and a_f) (b)*

Three-dimensional model of the structure allows to evaluate the distribution of the plasticity induced crack closure along the crack front. Both cases, straight crack front and crack with real curvature observed experimentally are compared. Presented results can help to describe more accurately crack propagation in three-dimensional structures, taking into account effect of the free surface on crack propagation.

[1] Elber W. Fatigue Crack Closure Under Cyclic Tension. Eng Fract Mech 1970;2:37–45.

[2] Pokorný P, Vojtek T, Náhlík L, Hutar P. Crack closure in near-threshold fatigue crack propagation in railway axle steel EA4T. Eng Fract Mech 2017;185:2–19. doi:10.1016/j.engfracmech.2017.02.013

Acknowledgement Financial support was provided by the Grant Agency of the Czech Republic (18-03615S) and infrastructural project m-IPMinfra (CZ.02.1.01/0.0/0.0/16_013/0001823). The equipment base of research infrastructure IPMinfra were used during the research activities.

‚Influence of humidity on near-threshold fatigue crack propagation in steels used in railway or civil industry

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Abstract Fatigue crack initiation and propagation in engineering structures could lead to fatigue failure with disastrous consequences. In the case of variable amplitude loading one of the most significant factors which influence fatigue lifetime is threshold value. This value separates a load spectrum into two parts: first part with cycles of high load amplitudes which contributes to crack propagation and second one with cycles of low load amplitudes which does not. This work shows a strong influence of humidity on measured threshold values for three different steels (steels EA4T and EA1N used for manufacturing of railway axles and steel S355J0 used for constructions of structural elements of bridges or cranes). In the case of railway axle steels the M(T) specimens (with parameter 2W=60 mm, thickness t=5 mm) were used and fatigue crack propagation tests were measured at load ratio R = -1. First part of specimens was measured in laboratory air (with natural humidity) and second part was measured with special chamber for reduction of humidity, see Figure 1. In the case of EA4T there is a drop of threshold value $K_{max,th}$ from 7 MPam$^{1/2}$ (naturally humid air) to 4.4 MPam$^{1/2}$ (dry air), see details in [1].

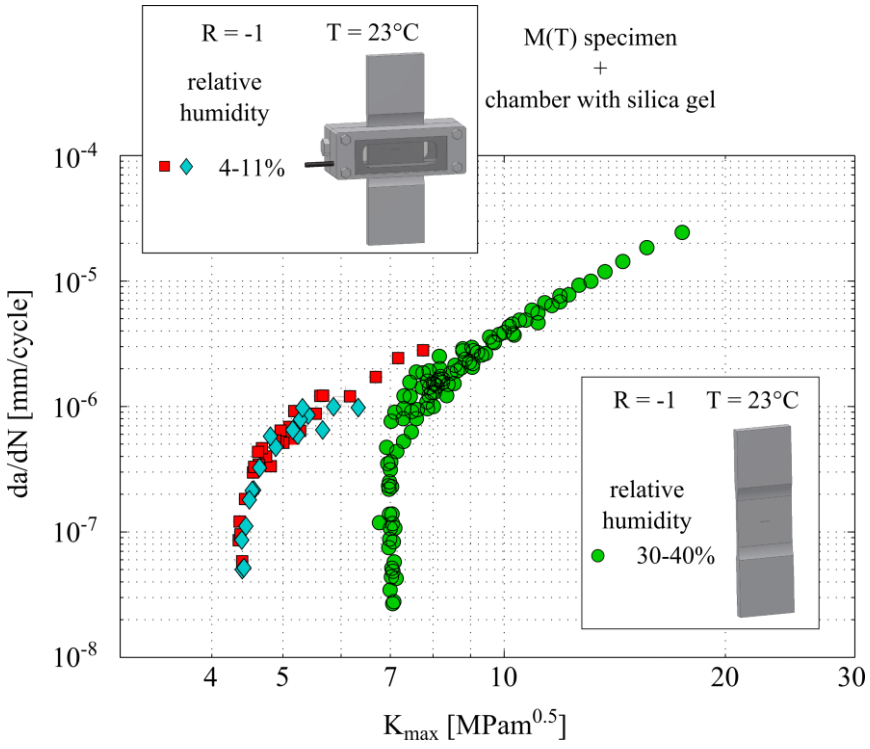

Figure 1 - *Effect of humidity on threshold value – railway axle steel EA4T*

Similar behaviour exhibits steel S355J0 used mainly in civil industry, see Figure 2. In this case influence of humidity on threshold value was experimentally determined at CT specimens (with parameter W=50 mm, thickness t=10 mm) at load ratio R = 0.1. The measurement of fatigue crack growth rates was done in two different periods of year: summer and winter. In summer natural relative humidity in laboratory was in range from 50-65%, but in winter natural humidity in laboratory was below 30%. Summer conditions lead to threshold value $K_{max,th}$ 7-10 MPam$^{1/2}$ and winter conditions (when air is naturally dry) to 4.5-5 MPam$^{1/2}$.

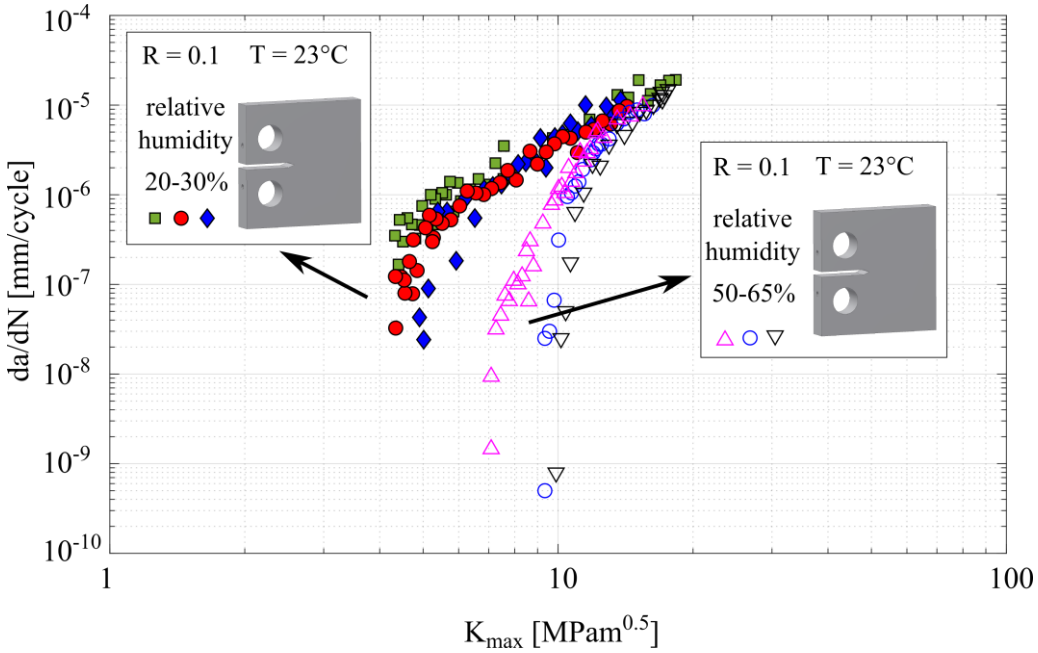

Figure 2 - – effect of humidity on threshold value – steel S355J0

Measured reduction in threshold value is dominantly caused by phenomena of oxide induced crack closure, see [1] or [2]. Measured drop in threshold values which is caused just by change of humidity level is so immense, that there can be enormous change in fatigue lifetimes. Therefore, effect of humidity should be considered for fatigue lifetime predictions and environmental spectra could be important for such type of steels.

[1] Pokorný P, Vojtek T, Náhlík L, Hutar P. Crack closure in near-threshold fatigue crack propagation in railway axle steel EA4T. Eng Fract Mech 2017;185:2–19. doi:10.1016/j.engfracmech.2017.02.013

[2] Suresh S, Zamiski GF, Ritchie RO. Oxide-Induced Crack Closure: An Explanation for Near-Threshold Corrosion Fatigue Crack Growth Behavior. Metall Trans A 1981;12:1435–43. doi:10.1007/BF02643688.

Acknowledgement Financial support was provided by infrastructural project m-IPMinfra (CZ.02.1.01/0.0/0.0/16_013/0001823). The equipment base of research infrastructure IPMinfra were used during the research activities.

, Fatigue behavior of different geometry scaffolds for bone replacement

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Abstract When transplanting bone tissue is not a possibility, tissue engineering is responsible for developing solutions to substitute the functions of the missing bone structure or support the process of bone regeneration. One of the most important solutions is the use of scaffolding. Scaffolds can be used to fulfill this mission by supporting the loads that were applied to the missing bone, supporting the cell regenerating process, allowing for the necessary nutrients and oxygen diffusion and delivering growth factors or drugs. Therefore, a feasible scaffold must be fabricated in a material with the necessary mechanical strength and that is non-toxic and biocompatible. The geometry design must support static and dynamic loads up to 20 MPa in order to replace human trabecular bone. Also, it should generate macro and micro pores to support cell growth and mineral precipitation, while all pores should be interconnected for nutrient and oxygen diffusion. In this paper two different scaffold geometries were analyzed. These scaffolds were produced by fused filament fabrication (FFF) of Poly(lactic acid) (PLA), using a commercial 3D printer (Blockstec-Zero). PLA is a biodegradable polymeric material, allowing for a customizable and inexpensive production of scaffolds for biomedical implants. Specimens were fabricated according to ASTM-695 standard (12.7x12.7x25.4 mm) using two different layouts. Figure 1 a) shows the orthogonal configuration with 90º between layers, while Figure 1 b) shows the isometric configuration with 120º between layers. All specimens were produced with 50% porosity and a theoretical distance of 0.8 mm between each filament. A nozzle of 0.4 mm in diameter was used, and the scaffolds were produced at 215ºC with a deposition rate of 30 mm/s. The specimen morphology was analyzed by scanning electron microscopy (SEM). It was possible to verify that scaffolds pores are interconnected, and the final scaffold dimensions are in good agreement with the theoretical ones. Several different FFF defects were also identified. Both geometries were fatigue tested using different load amplitudes, with a frequency of 0.25 Hz, until 3600 cycles. The specimen height during the test, the strain amplitude, deformation energy and the compression modulus were proportional to the applied stress amplitude. Lower stress amplitudes lead to a stable strain cycle and constant compression modulus, while higher stress amplitudes lead to an increased compression modulus due to layer collapse. The orthogonal scaffold showed an improved behavior with the compression modulus reaching 680 MPa, when a maximum stress of 14.4 MPa was applied. Therefore, both scaffolds show the potential to be used as implants for bone replacement in dynamic applications.

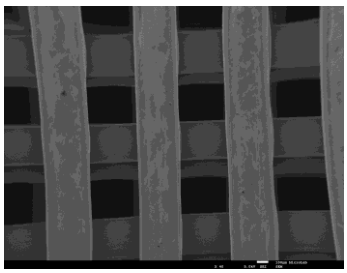
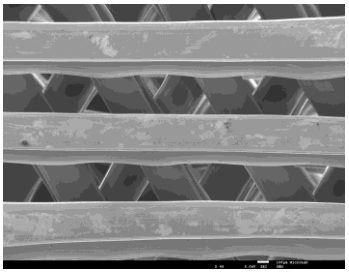
a)  b) 

***Figure 1** – SEM 40x (a) Orthogonal and (b) Isometric Scaffold Layouts.*

, An algorithm for fatigue crack growth applied to mixed and biaxial mode loadings

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Abstract Fatigue is still one of the main concerns when dealing with mechanical components failure. While it is fundamental to experimentally determine the fatigue material behavior using standard specimens, testing large and complex component geometries can be complicated. In these cases, the Finite Element Method (FEM) can be a cost-effective solution but developing fatigue crack growth models is still a complicated task. In order to solve this problem, an algorithm for automatic crack propagation was developed. Using three different modules, the algorithm can generate a complex FEM model including a fatigue crack; solve this model even considering complex loading conditions, by applying the superposition method; and calculate the fatigue crack propagation rate, using it to update the original model. The algorithm uses Python for the first module, Abaqus to solve the FEM problem and Matlab to update the model with the obtain fracture parameters. In order to benchmark this solution two different problems were analyzed. A modified compact tension (CT) specimen (Figure 1 a)) was modeled, including a hole with variable center location, to assess the performance of the algorithm when simulation fatigue crack growth in mixed mode conditions. By modifying the specimen hole location and by simulating an initial crack, it was possible to understand how the mixed mode conditions influence the fatigue crack path. The hole can attract the crack and be considered a sink hole, or the crack may be deflected but still miss the hole. It was possible to verify that the crack behavior is mainly influenced by the hole to crack vertical distance. In order to assess the influence of the loading conditions in the fatigue crack path, a cruciform specimen (Figure 1 b)) was modeled. The crack propagates in biaxial mode conditions and the crack trajectory depends on the proportional load ratio. Different initial crack directions were analyzed, showing that the crack will always propagate in a straight line if the load ratio is equal to one. Increasing the load ratio will then increase the crack deflecting angle. and the crack deflection angle increases with the load ratio. The obtain solutions were compared with experimental results showing good agreement. Therefore the developed algorithm can be used to predict the fatigue crack growth behavior on complex geometries and when different types of loads are applied to the component.

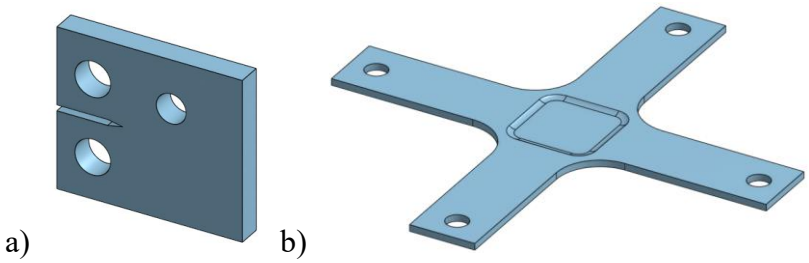

***Figure 1** – (a) Modified CT and (b) Cruciform specimens*

Acknowledgments

This work was supported by FCT, through IDMEC, under LAETA, project UID/EMS/50022/2019.

, Creep-ratcheting-fatigue life prediction of bainitic 2.25Cr1MoV steel

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Abstract Creep-ratcheting-fatigue properties of bainitic 2.25Cr1MoV forged steel were investigated at 455ºC. Peak and peak/valley holding periods were incorporated to explore the effect of creep on ratcheting-fatigue during cyclic loading. The peak/valley stress holding widened stress-strain hysteresis loop, while creep strain produced. Long peak stress holding period brought high strain energy density. Creep strain produced during peak holding transformed from instantaneously reversible to permanently irreversible as holding period extended from 2 s to 60 s. The elongation of either peak or peak/valley holding period would elevate the minimum strain rate of the steady ratcheting deformation stage and therefore shorten fatigue life. The linear damage summation rule gave satisfactory predictions for peak holding mode, but provided unsafe estimations for peak/valley holding mode, which were improved by introducing stress ratio into the evaluation of creep damage. However, 95% of fatigue lives in ratcheting-fatigue and creep-ratcheting-fatigue conditions predicted from the minimum strain rate method fell within a scatter band of 1.5. Therefore, minimum strain rate was considered as a critical control parameter of creep-ratcheting-fatigue life.

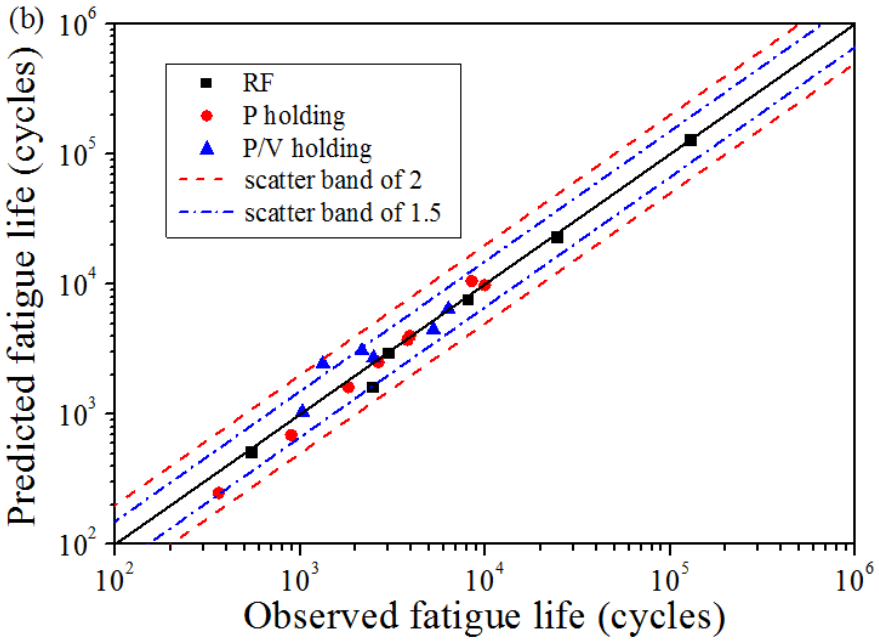

Figure 1 *– fatigue life prediction*

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Microstructural and environmental effects on the fatigue crack propagation of AM TiAl6V4 alloy specimens

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Abstract Additive manufactured (AM) parts made in TiAl6V4 alloy are increasingly used in medical devices and aeronautical industry, because of its high strength, low weight and excellent biocompatibility. Most of these components work under environmentally assisted cyclic loading, i.e. the corrosion-fatigue. Fatigue performance of additive manufactured alloys is significantly influenced by the porosities, residual stresses, which can be reduced by optimizing the process parameters, thermal treatments or hot isostatic pressing (HIP). Porosities, residual stresses and anisotropic microstructure of the AM materials can also contribute significantly to the propagation of cracks under corrosion-fatigue, needing steel significant research work.

Current work studied the fatigue crack propagation of titanium TiAl6V4 specimens produced by selective laser melting (SLM), comparing the response of samples subjected to stress release treatment and HIP processes. Environmental effect was obtained studying the corrosion-fatigue crack propagation in corrosive solutions, namely artificial saliva. Tests were performed using standard 6 mm thick compact specimens (CT) and tested at R=0. The main objective was to study the effect of the heat treatment and environment solution on da/dN-ΔK curves and on the fatigue failure mechanisms.

, **Laboratory method for simulating hydrogen assisted degradation of gas pipeline steels**

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Abstract Integrity of natural gas transmission systems is of great importance for energy and environmental security. Deterioration occurs in natural gas transit pipelines due to operational conditions and action of corrosion and hydrogenating media and leads to changes in microstructure and mechanical properties of pipeline steels, which influenced on pipeline performance. Hydrogenation of metal during corrosion process together with working stresses facilitates a development of in-bulk damaging at nano- and microscales. It provokes not only a development of macrocracking in pipes but also is often the main reason of decrease of pipeline steels characteristics of brittle fracture resistance under long-time operation. Reducing the fracture and impact toughness and increasing susceptibility of pipeline steels to stress corrosion cracking, which increases significantly a risk of uncontrolled failure of gas pipelines by subcritical crack propagation, is associated with in-bulk material degradation.
Therefore hydrogen assisted degradation of transport pipelines steels under operation calls for effective methods for in-laboratory accelerated degradation. The present study is devoted to the development of the procedure of laboratory simulation of in-service degradation of pipeline steels. The procedure of accelerated degradation of pipeline steels under the combined action of axial loading and hydrogen charging was developed and induced in the laboratory. The steel specimens before testing were subjected to in-laboratory accelerated degradation procedure, consisted in consistently subjecting of the specimens to electrolytic hydrogen charging, to an axial loading up and to an artificial aging. Pipeline steels in different states (as-received, post-operated and after in-laboratory degradation) were investigated. The tensile mechanical behavior of pipeline steels was experimentally studied. Susceptibility to stress corrosion cracking and impact toughness of tested pipeline steels were estimated. The characteristics of the operated pipeline steels were compared with the properties of pipeline steels after accelerated degradation.
It was definitely concluded that the applied procedure causes the changes in the mechanical properties of the metal at the same level compared to the properties degradation due to long-term operation. The developed procedure of in-laboratory accelerated degradation of pipeline steels enables, on a laboratory scale, simulating of the degradation of the pipeline steel during long-term operation under simultaneous action of hydrogenation and working loading, and it makes it possible to predict the susceptibility of operated pipeline steels to stress corrosion cracking.

Acknowledgements

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, Very high cycle tests of high strength steels S355 J0 and S355 J2

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Abstract: The high strength steel S355 is frequently used in civil engineering to design bridges, its elements or simple engineering parts. The properties of the steel lead to savings both material's and economical meeting strict construction requirements. From this reason, fatigue resistance of the material is in focus of researchers. Results obtained from experimental observations provide reliable inputs to lifetime assessments and numerical simulations of bridge structures and other constructions. As these constructions are designed for a long life, we have studied the properties of material in the field of high-cycle and very high-cycle fatigue. Tests of two standard S355 J0 and S355 J2 steel grades were performed on ultrasonic fatigue testing system. Both steels exhibited fatigue behavior in gigacycle region while S355 J2 exhibited higher number of cycles to failure. Fracture surfaces were studied and showed both surface and subsurface crack initiation.

Acknowledgements

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'Investigation of Structural Integrity of Composite Materials using Wavelet Packet Transform

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Abstract: Carbon Fiber Reinforced Plastics (CFRP) laminates are tested using Acousto-Ultrasonic Approach. The materials are subjected to out of plane impact and the Acousto-Ultrasonic Approach is used to test the materials both before and after the impact event. The Waveform of the recorded signal before and after the impact is used to characterize the structural integrity of the material. The recorded Waveforms are decomposed into lower levels to identify the frequency band associated with the recorded signals. Wavelet Packet Transform (WPT) analysis was used to decompose the Wavelets. The WPT analysis is preferred over the conventional Discrete Wavelet Analysis (DWT) owing to the possibility of analyzing both the approximation and details of the decomposed Wavelet. From the WPT results, the spectral energy in the time domain associated with each of the recorded wavelets are analyzed. The spectral energy is successfully used to characterize the integrity of the CFRP material before and after the impact event. The magnitude of the spectral energy in both the longitudinal and transverse direction of the specimen is observed to be lowered after the impact event. Using this technique, it is possible to characterize the integrity of the material even before it is subjected to loading.

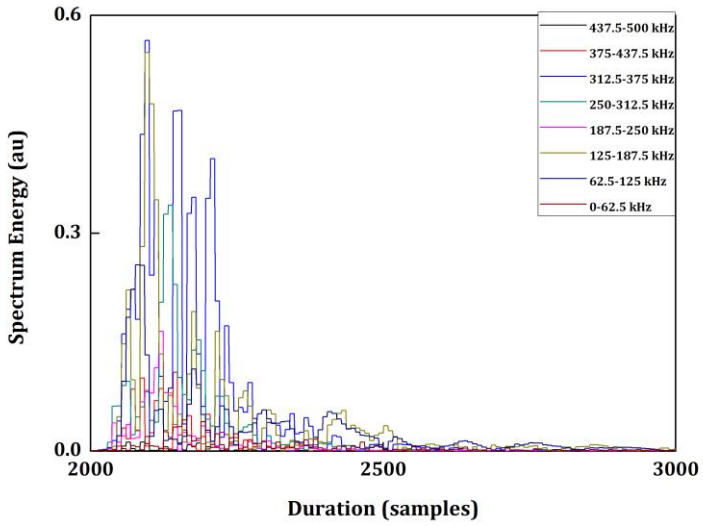

Figure 1 – *Spectral Energy of the Recorded Waveform in Transverse Direction after Impact*

Fatigue life prediction of Polymethyl methacrylate (PMMA) polymer under random vibration loading

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Abstract: The fatigue failure of Polymethyl Methacrylate (PMMA) polymer material components of an automotive lamp is a common occurrence. Currently, because of complex structural elements, virtual prototypes are not available. Lamp assemblies are subjected to accelerated random vibration tests during design to assess their integrity over a life time exposure to random vibration loading. Often, the optical components made of PMMA fail by fracturing during accelerated random vibration test. This results in a costly and time consuming design cycle as design changes and modification of the injection moulding tool are needed. Numerically predicting the fatigue life of this optical component prior to producing an assembly prototype will eliminate these shortcomings. However, there are challenges in numerically predicting the fatigue of polymers. The polymers exhibit complex behavior during deformation - the stress-strain relationship of polymers is notably non-linear within the elastic limit and they also exhibit inter-sample variation due to manufacturing processes. The key to developing an accurate model to predict the fatigue life of PMMA material is a good understanding of its complex behavior.

The objective of this paper is to develop a robust numerical fatigue life prediction model for PMMA polymer material of automotive lamp components subjected to random vibration loading, with consideration for material non-linearity. The fatigue life based on initial elastic modulus and secant modulus is predicted using ANSYS software and compared to the experimentally obtained fatigue life. Three fatigue life prediction models, Steinberg, Narrow-Band and Wirsching were used. Twelve specimens cut-out from injection moulded optical blades of PMMA were tested to obtain the fatigue life. All the specimens have a double sided u-notch positioned 10mm from the clamp and block steel was bonded to the tip to generate weight. The specimen connected to the test fixture was driven by electrodynamic shaker using standard automotive random vibration loading.

The average experimental fatigue life was obtained from the twelve specimens tested. The use of initial elastic range based modulus gives fatigue life that is 47% lower than the experimental result, while for the secant modulus based analysis, the fatigue life accurately matches the experimental result with only 1.6% difference. The significant error in the result of initial elastic modulus clearly reflects the evidence of material non-linearity. The numerical result is based on Wirsching fatigue model, which provides a more accurate prediction than Steinberg and Narrow-Band models.

, Dynamic response and fatigue life of Vacuum cast Polyurethane polymer material

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Abstract: The objective of this paper is to measure the dynamic response transmissibility and fatigue life of vacuum cast Polyurethane polymer material used in the construction of automotive lamps. Polymers used in automotive lamps, if mass produced, are injection moulded. For Ultra Low volume production, however, the cost of tooling for these traditional manufacturing methods is often very high. Hence, alternative approaches such as Silicone Tool – Vacuum casting are used. These alternative approaches may result in inferior dynamic performance, which is the subject of this research.

Automotive lamps, like other automotive components, are subjected to vibration loading during vehicle operation. In order to ensure that the lamps are robust enough to withstand the exposure to this vibration loading over their life cycle, durability tests are performed during the design. The light weight, good mechanical properties and design flexibility of polymers make them the preferred choice of material for constructing automotive lamps. However, the vibration induced fatigue failure of lamp assembly of polymer materials during the durability testing is notably challenging. Designing a robust lamp assembly essentially requires a good understanding of the dynamic behavior and fatigue life of materials involved.

In this paper, the dynamic response and fatigue life of vacuum cast polyurethane are assessed. The specimens for dynamic response and fatigue testing were cut-out from a vacuum cast polyurethane plate. An instrumented beam was mounted on a shaker table and using sine sweep base excitation the dynamic response was measured. Using measured acceleration, response transmissibilities were calculated. The degree of nonlinear behavior was investigated by varying the input amplitude. The bending fatigue properties were measured using a 4-point bending based resonance test apparatus. The apparatus with the test specimen was mounted on the shaker to generate base input. The beam was then excited at the first natural frequency but at varying base acceleration to find the fatigue properties. A series of tests were carried out to obtain average performance parameters.

The dynamic response shows nonlinearity, as expected of polymers, and large variation in dynamic response is observed from $1m/s^2$ to $30m/s^2$ input loading. Above $30m/s^2$ input, the variation in the dynamic response becomes minimal. The obtained fatigue life curve shows scatter which increases as the loading decreases. The microscopic fractography of the fatigued specimens shows morphological variation. An in-depth discussion of this phenomenon is given.

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Integral Structures of the Future: Recommendations from Materials Engineering

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Abstract Airframes of commercial aircrafts offer the greatest challenge to realize lightweight design. To achieve weight reduction of the aircraft and to improve passenger safety at the same time, lightweight load-bearing structures of high performance have to be developed. For metallic fuselage, one innovative way is to use welding instead of riveting. Due to significant advantages pertaining to production costs, weight, and corrosion resistance, there is an increasing use of advanced joining technologies such as laser beam welding (LBW) and friction stir welding (FSW) for the production of metallic civil aircraft structures [1].

The two joining techniques LBW and FSW lead to a type of structure that is close to an integral structural design. This design offers benefits from the weight-reduction and manufacturing-cost points of view. The reason why these techniques do not find a more widespread application is clearly linked to the inferior damage tolerance behavior of the welded integral structures [2]. To assure safety requirements as well as to achieve further gains in structural performance of welded structures, local modification technologies should be implemented [3-8]. One of the most important concerns in the design of airframe structures is related to fatigue issues [2]. Therefore, before welding is widely applied in more sensitive areas of the fuselage construction, it is necessary to achieve significant improvements in fatigue resistance and residual strength of the welded structure. In this context, the residual stress-based methods can be applied, which can significantly improve the fatigue behavior of the metallic structures [3].

The present study deals with innovative joining processes applied to high-strength aluminum alloys used in the aircraft industry and displays their advantages compared with the riveting technique regarding structural integrity, weight and material savings. Since the development and industrial implementation of CO_2 LBW for aluminum airframe fuselage components at Airbus by the end of last century [2], local engineering techniques were further developed, that can significantly improve the fatigue resistance of fuselage structures [3-8]. The present works demonstrates current achievements in application of local engineering techniques for airframes. The techniques are based either on optimization of structural design (e.g. introducing of systematic thickness variations [4]) or on introduction of beneficial residual stresses using advanced laser processes such as laser heating [6] and laser shock peening [7].

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, The effect of cryogenic suction on the monitoring data of ice barrier formation in a porous water-saturated soil

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Abstract Ice wall formation is one of the most frequently used techniques for waterproofing of mines constructed in water-saturated rock massifs. In this work, we have developed a complex intelligent monitoring system for control of formation of ice wall at the first shaft of the Petrikov mine. The system includes hydro-observation and temperature monitoring wells combined with simulation module. The two hydro-observation wells of depth 82 m and 202 m located around the periphery of the mine shaft. The several wells are used for temperature monitoring by original fiber-optic measuring system developed at the MI UB RAS.

At the beginning of the monitoring process, we observed contradictory indications of ice wall closing moment by hydro-observation and temperature monitoring parts of the systems. One of the possible explanation of this effect is initiation of intensive cryogenic suction. To study this effect we introduced in the simulation module three models of ground freezing, which variously consider (in different combination) the key effects observed during the propagation of the phase transition front in a saturated soil (the nonequilibrium moisture content in the soil at negative temperatures, kinetic peculiarities of water-ice transition in a porous medium and redistribution of moisture in partially saturated soil).

Based on the detail simulation model we have shown that moisture content inside the closed ice wall can decrease due to water migration towards the phase transition front, which, consequently, slows down the water yield of hydro-observation wells. Analysis of the solution of the problem on the coalescence of two frizzing zones showed that the redistribution of moisture content leads to a decrease of humidity in the coalescence region and, as a consequence, to inhomogeneous content of ice in the ice wall. In particular, the difference in ice content was by more than 30% at the points near the freeze column and at the points of closure of the frozen zones.

The redistribution of moisture content is pronounced in partially saturated soil in the inner closed region of the growing ice wall. The motion of the liquid towards the front of phase transition leads to a drop of humidity within the cylindrical ice wall by more than 10%. This effect can compensate for the pressure caused by a compression of the soil horizon during the water-ice phase transition and cause the slowing down of the water yield of the hydro-observation wells.

The complex model allows us to increase a precision and predictive ability the monitoring system and well control the process of formation and deformation ice wall at first shaft of the Petrikov mine.

The work was supported by the Russian Science Foundation (grant No. 19-77-30008).

Results of the ECO-COMPASS EU-China Project

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Abstract Fibre reinforced polymers are important materials used in aviation due to their excellent specific properties enabling the reduction of fuel consumption. For example, carbon fibre reinforced epoxy resins are used in fuselage and wing structures. Glass fibre reinforced phenolic resins are mainly used for the interior panels due to their low weight and favourable fire properties. All these composite materials used in aviation have one thing in common: they are man-made. Renewable materials like bio-fibres and bio-resins are under investigation for a long time for composites but they did not made it into modern aircraft in high amounts yet.

The project ECO-COMPASS under Horizon 2020 aims to bundle the knowledge of 19 partners from China and Europe to develop ecological improved composites for the use in aircraft interior and secondary structures. Bio-based reinforcements, epoxy resin and sandwich cores are developed and improved for their application in aviation. Furthermore the use of recycled carbon fibres to increase the mechanical strength and multifunctional aspects of bio-composites are evaluated. In order to withstand the special stresses in aviation environment, protection technologies to mitigate the risks of fire, lightning and moisture uptake are under investigation. An adapted modelling and simulation will enable the optimization of the composite design. Electrical conductive composites for electromagnetic interference shielding and lightning strike protection are under investigation in ECOCOMPASS as well. The cooperation includes the exchange of knowledge and materials in order to optimize the development of ecological friendly composites.

The aim of the presentation at the ICSI2019 conference is to give an overview of the project objectives and its special background with the collaboration of Chinese and European partners. Selected topics and final results of the ECO-COMPASS project will be presented.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690638 and the Special Research Plan on Civil Aircraft of Ministry for Industry and Information of the People's Republic of China (MIIT) under Grant No MJ-2015-H-G-103.

, **The experimental investigation of freezing and thawing process in water-saturated soil based on FBG sensor system**

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Abstract The work is devoted to experimental investigation and numerical of freezing and thawing processes of the water-saturated porous soil. As is known, the thawing and freezing processes of porous media are accompanied by the mass and heat transfer, the formation of cryogenic flows and changes in the stress - strain state of the medium. These effects have a significant influence on infrastructure and industry objects in north regions. Design and monitoring such objects need to develop numerical model which describes the adverted effects but every numerical model must be verified by natural experiments. Therefore, it is important to develop the laboratory setup for investigation of complex effects which accompany the phase transition in water-saturated soils.

In this work the fiber Bragg gages (FBG) is applied for analysis of the freezing process in water-saturated sand. The experimental setup consists of temperature and deformation FBG sensors, which located in different sections of cylindrical specimen. The temperature FBG sensors are equipped with quartz shell for protection from deformation. Temperature of process also effects on deformation of FBG sensors. It is important to make temperature compensation procedure after measurements.

Also in the present work the numerical simulation of freezing process was carried out. Two different models of phase transition are considered. The main difference between the models is the possibility to take into account non-equilibrium humidity during phase transition. Calibration of material parameters for sand and parametric identification of models are carried out by the solution of inverse problems.

As a result, it has been shown the possibility to determine quality evolution of strain during the freezing in different areas of specimen using FBG sensors. The temperature compensation was performed to determine the value of strain. The temperature distribution in volume was obtained by protected temperature FBG sensors and confirmed by thermocouple detectors. The numerical simulation allows us to define material parameters of tested soil. The non-equilibrium humidity and phase transition rate obtained by simulation are in a good agreement with the experimental results.

The work was supported by the Russian Science Foundation (grant No. 17-11-01204).

, High-Strain-Rate Loading of Friction Stir Weld-Bonded Joints

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Abstract Friction Stir Welding (FSW) is a high performing solid-state joining process. It's good mechanical performance and operational benefits have led its push for industrial adoption. However when welding in overlap configuration leads to significantly lower performance when compared to butt-joining, limiting the potential industrial application of this welding technology. To overcome this drawback hybrid Friction Stir Weld-Bonding, combining FSW and adhesive bonding (AB), has been proposed. Safety critical structural applications such as in aeronautical fuselages or automotive body in white (BIW), can be subjected to high strain-rate loading. The performance of such joints when subjected to high-strain-rates is a critical input for design engineers and will be required for further adoption of the joining method in such structures. In this work a testing apparatus was developed to load single lap joints at varying high-strain-rates and Friction Stir Weld-Bonded joints were tested. Benchmarking was made against AB and FSW joints.

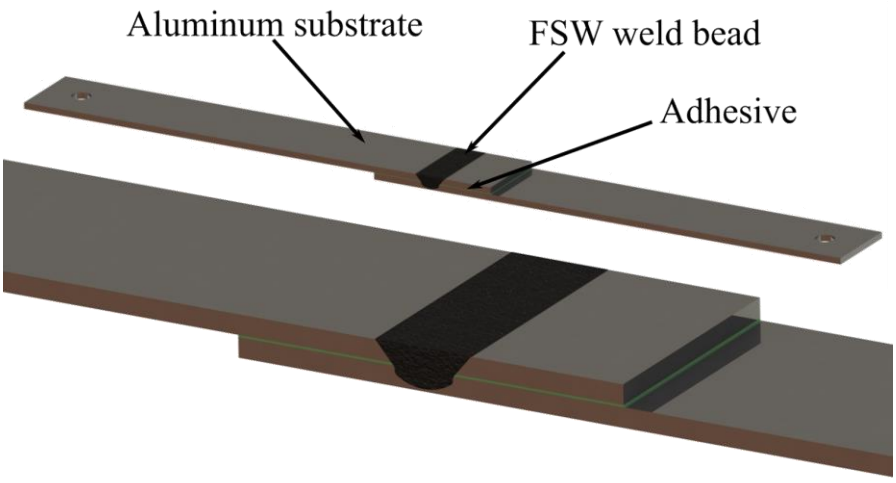

Figure 1 *– Scheme of Friction Stir Weld-bonded joint*

, Fracture Resistance of Alkali Activated Concrete under the Mixed Mode I/II Load Conditions

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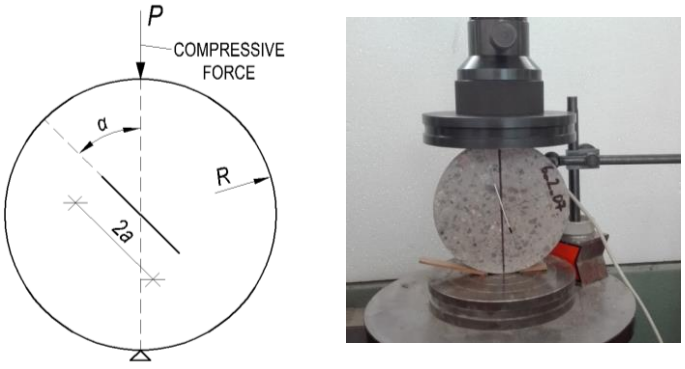
Abstract Nowadays, traditional concrete mixture uses as a binder well known Portland cement. However, the production of the Portland cement is not environmentally friendly, due to high production of CO_2 in the fabrication process. In recent years, there are some trends to use secondary materials as a binder or as replacement of aggregate in the process of making the concrete mixture. This modified material uses alkali reaction in the hardening of fresh mixture, therefore an alkali activated concrete (AAC) term is used. This AAC is then used in formwork as it was traditional concrete, due to similar properties. Despite the use of advanced material, standards for structural design do not provide any instruction for practical application. Subsequently, the knowledge of fracture of this material is limited. The fracture mechanical properties help to perform advanced structural analysis, especially when some of the structural elements have a crack. The load presence on the structure can be divided into tensile, shear, and into combination of tension and shear. Therefore, it is necessary to perform test, which covers mixed mode I/II loading conditions. One of the tests usually used for the evaluation of fracture resistance of concrete is the Brazilian disc test with a central notch. This contribution evaluates the fracture resistance of alkali activated concrete, which will be used as a replacement for traditional structural concrete with cement binder, subjected to mixed mode I/II loading. The generalized maximum tangential stress (GMTS) criterion was used for the evaluation of the fracture resistance curve.



(a) (b)

Figure 1 - *Brazilian disc with central notch – loading scheme (a) and actual test setup (b).*

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Transverse load influence on tensile fatigue resistance of high-strength steel wires for structural applications in civil engineering

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Abstract: Today, multi-wire strands manufactured with high-strength cold-drawn lean duplex stainless steel are an emerging alternative to the conventional ones, made of cold-drawn eutectoid steel to significantly reduce the stress corrosion risk when employed in prestressed concrete or in post-tensioned structures as stay cables. One of the uncertainties that raises from this application is the behavior of lean duplex wires under the combined action of cyclic tension and transverse loads that occur due to their mutual contact in the multi-wire strands or due to the strands deviation in the anchorage or floating coupling systems.

In this view, present research experimentally assesses and compares the behavior of high-strength lean duplex wires with that of prestressing eutectoid steel wires when subjected to such biaxial loadings, namely tensile fatigue and static transverse, local compression. The results indicate that both wire types, even when supporting transverse compression loads of almost 40% of their tensile strength, preserve the fatigue endurance limit required by the current standards for prestressing steel wires, free from transverse loads. The detected failure mechanisms in both cases, although similar at macroscale, are fully distinct at microscale and strongly related with each microstructure type (Fig 1).

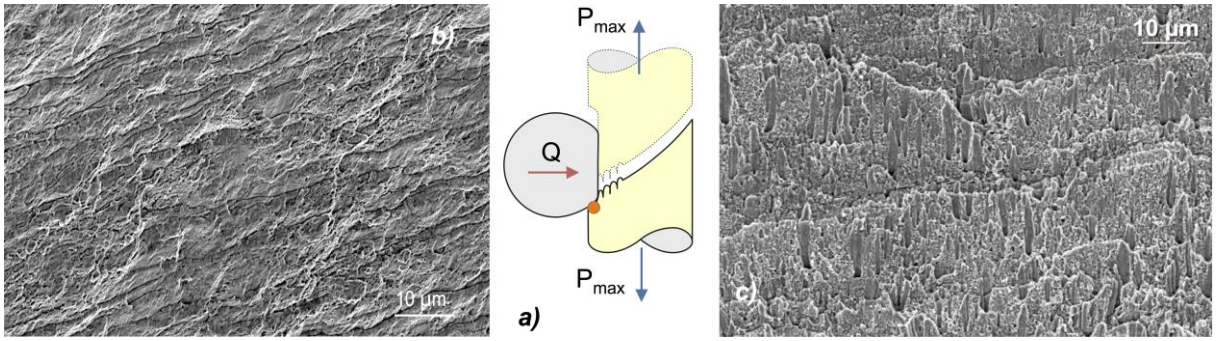

Figure 1. *a) Sketch of the tensile fatigue test under transverse load showing the inclined failure origin; Fatigue marks in: b) Lean duplex stainless steel wire; c) Eutectoid steel wire.*

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Water tanks construction using post-tensioned precast concrete

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Abstract Three water tanks were required for the support backup system of the fuel operating group and cargo complex of the Lisbon Airport. The short timeline of the project was determined by two factors: the immediate need for the tanks and the job site located inside the airport, near the landing runway. The largest of the three tanks – 20 m in diameter – needed to hold about 1700 m^3 of water. A post-tensioned precast concrete solution was assessed, allowing for greater quality control of the manufactured products, increased speed of installation and lower impact of the construction. As a result, a very thin, cost-effective, wall structure, made of prestressed concrete, was designed. The exterior wall panels were cast using a conventional concrete mix and were joined by post-tensioning.

Figure 1 – *View of the largest tank*

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Influence of the SMA constitutive model on the longitudinal seismic response of RC bridges

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Abstract Several studies indicate that the re-centring capacity presented by superelastic Shape Memory Alloys (SMA) can reduce the displacements of structures subjected to earthquakes. To quantify the errors of numerical predictions with different constitutive models, peak, relative and residual displacements of four two-frame reinforced concrete (RC) bridges, linked by SMA bars, subjected to seismic actions, were numerically assessed. Different ratios of the elastic natural period of vibration of the frames of the bridges were adopted. Lumped plasticity models were used to simulate the behaviour of the reinforced concrete columns. Five SMA uniaxial models were considered, combining linear, nonlinear, isothermal and nonisothermal conditions. The seismic action was modelled by real accelerograms.

The results shown that the relative displacements are more sensitive to the adopted SMA model than the peak and residual displacements. Significant relative differences, up to 70%, were obtained.

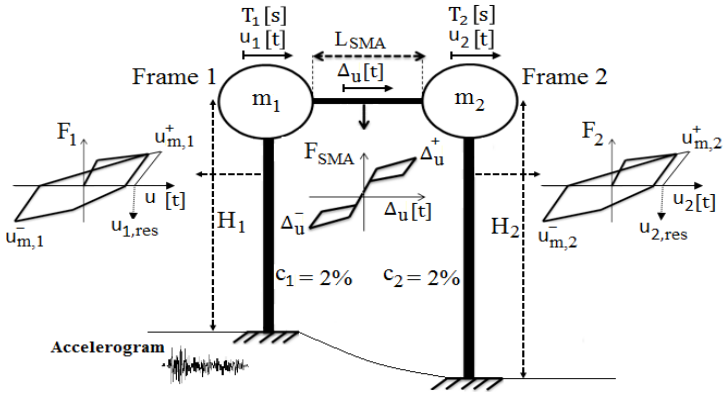

***Figure 1** – Model of the two-frame reinforced concrete bridges*

, **On the Hydrogen State and Its Role in the Stress Corrosion Cracking of AZ31 and ZK60 Magnesium Alloys**

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Abstract High susceptibility of magnesium alloys to the stress-corrosion cracking (SCC) is among the main reasons impeding their use by the industry. Although it is believed that the SCC of Mg is associated with hydrogen embrittlement, the exact role of hydrogen in the crack growth process is unclear. To address this issue in the present study the round specimens of AZ31 and ZK60 alloys were slow strain rate tensile (SSRT) tested in air as well as in corrosion solution. The gauge parts of the SSRT-tested specimens were subjected to the hot-extraction hydrogen gas-analysis before and after chemical removing of corrosion products. For both the alloys strong drop of mechanical properties as well as substantial increase of hydrogen concentration due to the SSRT testing in corrosion media are observed. Before removing of corrosion products desorption of hydrogen is found in the whole temperature range from 25 to 450 °C However no detectable desorption of diffusible hydrogen (i.e. below 300 °C) is found after removing of corrosion products. Therefore it is concluded that: (i) the concentration of diffusible hydrogen in the matrix of the alloys subjected to SCC is negligible; (ii) the desorption of hydrogen below 300 °C from the specimens covered with corrosion products is associated with decomposition of corrosion products. It is suggested that access of diffusible hydrogen into the metal's matrix is restricted by the surface film of Mg hydride and/or hydroxide which decomposition results in hydrogen desorption peak at around 450 °C on extraction curves for both the alloys. The mechanism, including alternated formation and brittle cracking of the surface film of hydride, is assumed to be responsible for the SCC of AZ31 and ZK60 alloys.

Financial support from the Russian Science Foundation through the grant-in-aid No. 18-19-00592 is gratefully appreciated.

, Assessment of the Mechanical Integrity of a 2 mm AA6060-T6 Butt Weld Produced Using the Hybrid Metal Extrusion & Bonding (HYB) Process – Part II: Tensile Test Results

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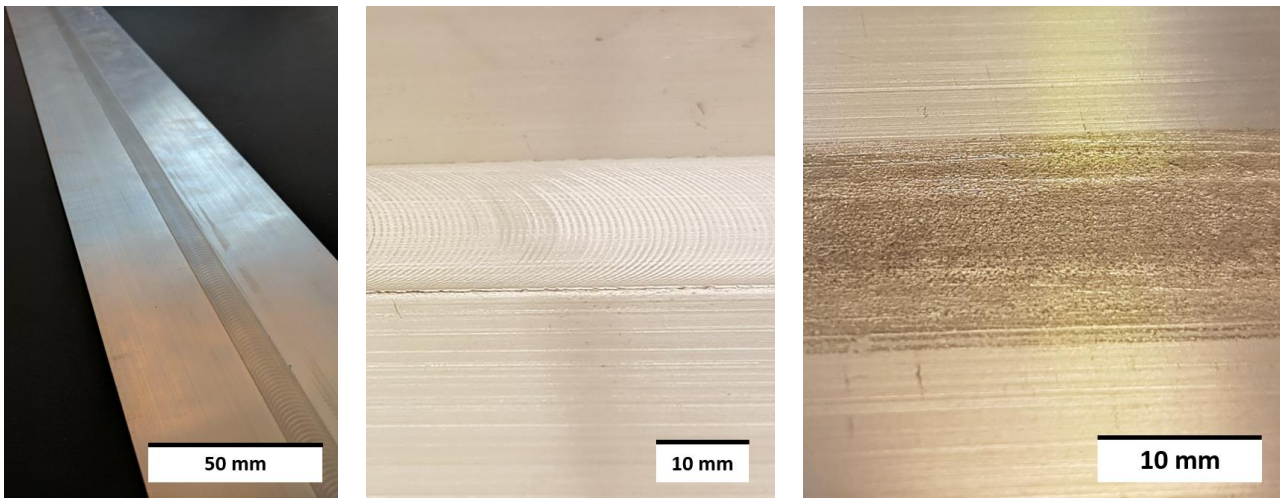
Abstract The Hybrid Metal Extrusion & Bonding (HYB) process is a new solid state joining technique which, by the use of filler material addition, enables joining of both similar and dissimilar metals [1]. The present investigation is concerned with butt welding of 2 mm thin AA6060-T6 profiles at room temperature (RT), using the HYB process and AA6082-T4 as filler material. In the as-welded condition, the 1000 mm long butt weld is seen to be straight and free from global distortions. At the same time both weld faces appear slick and display a nice surface finish. This is shown in Figure 1. In the present investigation, a more detailed examination of the weld mechanical properties will be given, by focusing on transverse hardness measurements and tensile testing of the joint. The joint reaches a relatively high yield strength of 146 MPa, which is in the range of that reported for comparable friction stir welds produced using high strength 6000 series aluminum alloys as base material.



(a) (b) (c)

***Figure 1** – Photographs of the 2 mm AA6060-T6 HYB butt joint; (a) Overview of the as-welded profile, (b) Close-up of weld face, (c) Close-up of weld root.*

1. Ø. Grong, L. Sandnes, and F. Berto, *A Status Report on the Hybrid Metal Extrusion & Bonding (HYB) Process and Its Applications.* Material Design & Processing Communications, 2019. **0**(ja): p. e41.

, Fatigue damage analysis of offshore wind turbine monopile weldments

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Abstract Offshore wind turbines (OWT) are subjected to harsh environmental conditions in addition to the variable service loads. The present study is aimed at performing a realistic fatigue life estimation of the monopile structure using operational service loads recorded by online monitoring systems. Fatigue damage analysis has been conducted at the circumferential weld joints using finite element (FE) method by considering geometrical and material property discontinuities as well as welding residual stresses. Coupon scale modelling results on welded joints have shown that in as-welded condition, the weld toe is the critical site where cracks are most likely to initiate and propagate. The S-N fatigue design approach and maximum stress amplitude at the weld toe have been used to determine the fatigue crack initiation life in monopiles in the presence of residual stresses. Consequently, the remaining life of the monopile has been estimated by simulating the fatigue crack propagation using the stress intensity factor range as the appropriate fracture mechanics parameter. The results from the proposed approach show that a realistic life assessment can be made on monopile structures by accounting for the geometrical effects as well as residual stress distribution at the circumferential welds.

, Research of fatigue durability construction GFRP under increased temperatures

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Abstract The actual tasks of the mechanics of composite materials are studies of the laws of deformation, fracture and mechanical behavior of composites under the influence of high and low (working) temperatures, climatic factors and working dirty environments. No less urgent task is to study issues related to the analysis of the conditions of destruction, the accumulation of damage and the survivability of composites during cyclic loads. In connection with the above tasks, the paper presents the results of experimental studies of the effect of high temperatures on the fatigue life of aviation structural fiberglass plastics. Studies were conducted at the Center for Collective Use of the Center of Experimental Mechanics PNRPU on an Instron 5882 universal electromechanical test system equipped a temperature chamber with working temperatures from –100 to 350ºC and cyclic loads were conducted on electrodynamic test system ElectroPuls E 10000 equipped a temperature chamber with working temperatures from –100 to 250ºC. The longitudinal deformations of the samples were measured by an AVE Instron 2663-821. The objects of the study were samples of structural fiberglass for aerospace purposes, which were manufactured by serial technology of autoclave molding from glass fiber prepreg.

In the course of research, static mechanical characteristics were determined (refined), strain diagrams were constructed at normal and high temperatures, temperature dependencies of static tensile strength and elastic modulus were obtained, temperature dependences of fatigue life were obtained, and conditions for changing the fracture mechanisms of fiberglass samples were analyzed (fig. 1).

Figure 1 - *fracture of GFRP specimen after cyclic loads by increased temperature*

Acknowledgement. The research was performed at the Perm National Research Polytechnical University at support of the Russian Scientific Fund (project No. 18-79-00209)

, Phenomenological characteristics structural features research obtained during fibrous plastics standard tests

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Abstract The analysis of standard and approved methods for composite materials testing samples was carried out. The choice and reason of the optimal research direction, the plan for experimental and theoretical work with regard to the capabilities and features of the modern experimental equipment was made. Formed a plan of experimental studies to determine the basic characteristics of composite materials under tension, compression and shear as well as advanced tests using nontrivial methods of tension and compression samples with a hole (ASTM D5766 and ASTM D6484), bending of a curved beam (ASTM D6415) and compression of plates after impact (ASTM D7136 and ASTM D7137). In addition, the task for the manufacture of non-trivial samples was set.

CFRP samples were made in terms of 3D preforms in the form of strip samples in accordance with the requirements of ASTM D3039, ASTM D3410 and ASTM D5379. Standart (installation) test methods have been adapted for existing Instron equipment, with the corresponding methods formulated in the specialized Bluehill 2 software, and the necessary restrictions were set. Experimental studies of the polymer composite materials mechanical behavior were carried out according to standard methods for determining the installation characteristics of tension, compression and shear. The main mechanical characteristics of the presented composite materials are determined. Based on the test results, calculations of characteristics recommended by ASTM standards are carried out. In some cases, the tests were proceed using additional facilities for observation to increase the information content.

The plan for theoretical studies and modeling was formed. A mathematical description and development of methods for modeling structures of composite materials in the working areas of samples were carried out. In accordance with the plan experimental research are conducted for three options: an effective isotropic area, an effective anisotropic area, and a layered composite with textural layers of an effective anisotropic area. Boundary conditions for their fixation and loading were set. The formation of finite element meshes and test calculations were performed.

This work was carried out in Perm National Research Polytechnic University using the equipment of the Centre of Collective Usage «Complex test and diagnostic equipment for study of structural and functional materials properties under complex thermomechanical impacts» (http://www.ckp-rf.ru/ckp/353547/), with supported by the Russian Foundation for Basic Research (project No. 18-01-00763 A).

, Mechanical behavior of structural steel under biaxial low-cycle fatigue at room and elevated temperatures

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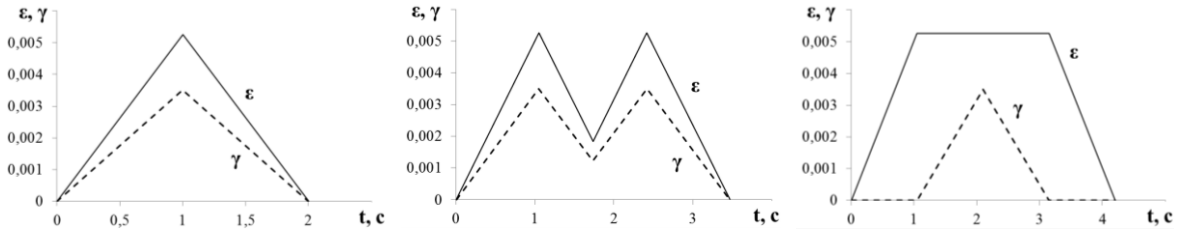
The results of experimental studies of the low-cycle fatigue characteristics of heat-resistant structural steel X15CrNi12-2 for aircraft purposes (chemistry: C - 0.13%; Cr - 12.5%; Si - 0.05%; Ni - 2.05%; Mo - 1.50% , W - 0.70%; Nb - 0.20%; V - 0.20%) under biaxial cyclic loading are presented. For cyclic tests a specialized Instron 8850 two-axes testing system was used, which allows the planning of cyclic and static tests with arbitrary stress sequence under the conditions of tension and torsion. The Epsilon 3550-010M dual-axis dynamic strain sensors for testing at normal temperatures and the Epsilon 3550HT-025M for testing at high temperatures were used to determine the values of axial and shear strains during the experiments. The test methods for biaxial cyclic loading under normal and elevated temperatures are described, which allow to analyze the mechanical behavior and structural steel destruction processes under plane stress conditions. Tests results of heat-resistant alloy X15CrNi12-2 under low-cycle fatigue at different temperatures and cyclic strain paths with proportional and non-proportional changes in axial and shear deformations are presented (Fig. 1). For different types of tests hysteresis loops are represented in the form of dependences of normal and shear stresses on axial and shear deformations, respectively. It is shown that the durability of X15CrNi12-2 steel in these parameters significantly depends on the cyclic strain path, the shape of the cycle and the test temperature. In the case of non-proportional deformation, the fatigue life of X15CrNi12-2 steel decreases 1.5-2 times as compared with proportional loading at different test temperatures. Depending on the strain path, a significant decrease in fatigue life at a temperature of 600 ° C by 17-44% in comparison with the room temperature was observed.



a) b) c)

Figure 1 - *Variation of axial (continuous) and shear (dashed) deformations under cyclic simple ((a) triangular and (b) M-shaped cycle modes) and complex (c) loading*

This work was carried out in Perm National Research Polytechnic University using the equipment of the Centre of Collective Usage «Complex test and diagnostic equipment for study of structural and functional materials properties under complex thermomechanical impacts» (http://www.ckp-rf.ru/ckp/353547/)

Fatigue Behavior of Carbon/Epoxy Non-crimp Fabric Composites for Automotive Applications

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Abstract Facing the stringent requirements for fuel economy in automotive industry, composite materials are seen to be utilized for structural lightweighting. This paper focuses on the fatigue test development and fatigue behavior of a biaxial [0/90] carbon/epoxy non-crimp fabric composites for automotive applications. A new fatigue test specimen was successfully developed for fatigue testing under fully reversed loading, i.e. stress ratio, R=-1 at room temperature and 130 ℃. The developed test specimen prevents buckling during testing without attaching an anti-buckling fixture. 3D Digital image correlation strain mapping also revealed a uniform strain distribution on the surface of this specimen geometry. Fatigue test results indicated that the fatigue behavior at both room temperature and 130 ℃ is matrix dominated (see Fig. 1). All the fatigue data were well fitted into the Basquin equation $\sigma_a = \sigma_f(2N)^b$.

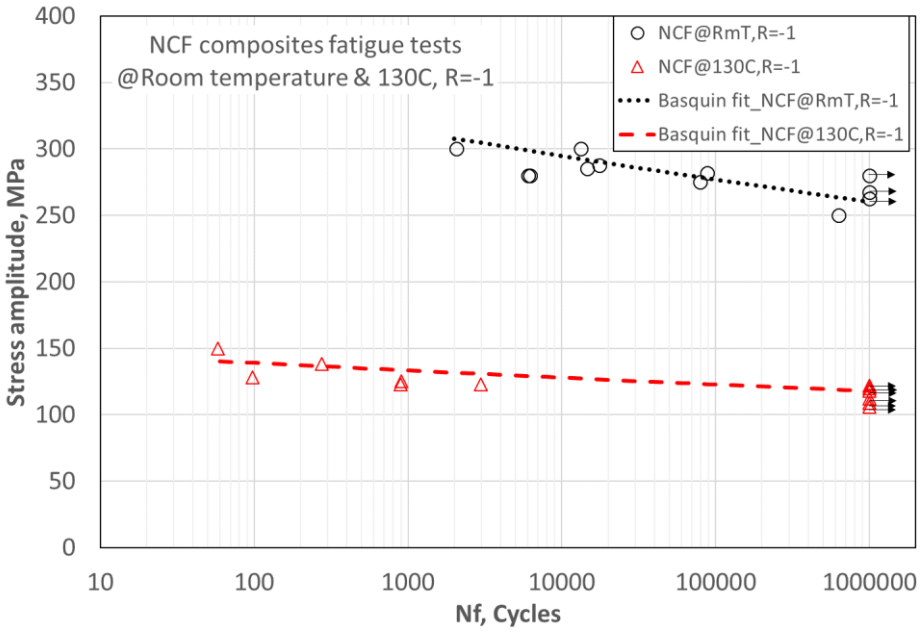

Figure 1 – Fatigue test results at room temperature and 130 ℃ under stress ratio, R=-1.

, Mechanical Treatment of Crack-Arrest Holes under Distortion-induced Fatigue

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Abstract

Fatigue cracking is a major concern for many aging steel bridges in the United States. A common form of crack remediation is the drilling of crack-arrest holes, increasing the crack tip radius and thus reducing the applied stress intensity. However, the majority of cracking that occurs in bridge structures is caused by distortion-induced fatigue in what is known as 'web gap regions' in plate girders. Cross-frame forces generated by differential girder displacement produce multiaxial, mixed-mode fatigue loading at the intersection of the girder web, flange, and connection plate, producing cracking along web-to-stiffener welds and flange-to-web welds. Crack-arrest holes are often used as a first line of defense at these cracks. However, crack-arrest holes deform out-of-plane under distortion-induced fatigue loading, and have been found to be of limited utility in this application.

Previous research has shown that mechanical treatment of crack-arrest holes has the potential to improve the efficacy of crack-arrest holes for halting crack propagation for in-plane fatigue, but the performance of such treatments is unknown for distortion-induced fatigue cracks. A research program sponsored by the Kansas Department of Transportation (KDOT) is investigating the effectiveness of one such technology for controlling crack propagation in steel bridge girders susceptible to distortion-induced fatigue. This technology produces a cold-worked region around the crack-arrest hole, introducing a field of compressive residual stresses aimed at retarding crack propagation. The research includes both analytical evaluation and physical experimentation. Testing is conducted on scaled girder-to-crossframe bridge components, providing a unique and realistic test specimen that mimics the distortion-induced fatigue experienced on steel highway bridges. A comparison is made between treated and untreated crack-arrest holes in terms of time-to-crack-reinitiation, and evaluation of hole sizing and location is performed. This paper will present background on the problem, an overview of the research project, and preliminary findings of the study.

, Examining the use of Digital Image Correlation for Detecting Distortion-induced Fatigue Cracks in Steel Bridges

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Abstract

Distortion-induced fatigue cracking in aging steel bridges is a primary concern for many bridge owners and stakeholders, accounting for the majority of fatigue cracks in steel bridges in the United States. Currently Departments of Transportation primarily use visual inspections to locate and characterize fatigue cracks. However, this approach has drawbacks, as recent studies have shown that visual inspections are not able to consistently identify realistically-sized fatigue cracks in highway infrastructure. Additionally, it requires significant time and cost to perform visual inspections, and both inspectors and the traveling public are placed at risk during the inspection. Bridge owners and stakeholders would benefit from the development of inspection techniques that do not rely on hands-on human visual inspection – to reduce the risks of harm to the inspectors and traveling public, increase reliability, and decrease the time and cost of performing inspections.

Vision-based technologies are an active area of research in the field of structural health monitoring, aimed at developing alternatives to manual inspection for identifying damage to transportation infrastructure. The majority of these studies have focused on macro-indicators of damage, including identifying excessive corrosion, concrete deck deterioration, and large displacements due to substructure movement. Digital image correlation (DIC) is one such vision-based technology that shows promise for detecting and characterizing fatigue cracks, but investigations and applications have thus far been limited to in-plane cracking.

Three-dimensional DIC measurements have the ability to capture full-field displacements and surface strains, allowing for the potential of identifying and characterizing out-of-plane fatigue cracks, such as those occurring on steel bridges exposed to loading through differential girder displacement. Since the majority of fatigue cracks arise from out-of-plane loading, investigating the efficacy of DIC for detecting distortion-induced fatigue cracks is of clear value.

This paper and presentation describe an experimental study in which a scaled steel girder-to-crossframe specimen was cyclically loaded to produce distortion-induced fatigue cracking in the girder. To examine the potential usefulness of DIC for future automated bridge inspections the resulting fatigue cracks were characterized using DIC and visual inspection. It was found that the DIC methodologies applied were capable of producing accurate and reliable crack detection results, introducing the potential for future automated techniques.

, The influence of polygonal cavity on fracture behaviour of concrete

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Abstract In this work, the influence of polygonal cavity on fracture behaviour of cement composite (concrete) is investigated. Specimens of the nominal dimensions 40 × 40 × 160 mm with polygonal cavity of 8 × 8 × 40 mm were provided with an initial central edge notch with a depth $a_0 = 12$ mm, which was made by diamond blade saw, see Fig. 1. To determine the influence of polygonal cavity on fracture behaviour, fracture tests were conducted via three-point bending.

The aim of this work is to analyse the behaviour of such specimen by means of finite element method (FEM) principles in Ansys, Inc. software. A simplified 2D model of plane strain based on the fracture test configuration was created. Materials were modelled as linear, elastic and isotropic, which are represented by their elastic constants, i.e. Poisson's ratio ν and Young's modulus *E*. The potential crack was modelled as ideally sharp with a radial mesh around the crack tip. The crack propagation assessment was based on criterion of an average value of tangential stress $\sigma_{\theta\theta}$ over a certain distance *d* determined in dependence on the polar angle θ. It is assumed that the crack is initiated when the average value $\bar{\sigma}_{\theta\theta}(\theta_0)$ reaches its critical value $\bar{\sigma}_{\theta\theta\,C}(\theta_0)$, which depends on the value of fracture toughness K_{Ic} of the material and on the distance *d*.

From the detailed numerical analysis of the described fracture test, we concluded that the actual crack depth a_0 must be greater. In other words, diamond blade saw damage the specimen more than expected. This damage is due to the small distance between the bottom peak of the inclusion and the crack tip, which is approximately 2.34 mm. It is obvious that such a small area above the crack tip cannot resist the load that is caused by cutting the specimen by diamond blade saw and must inevitably lead to its partial failure.

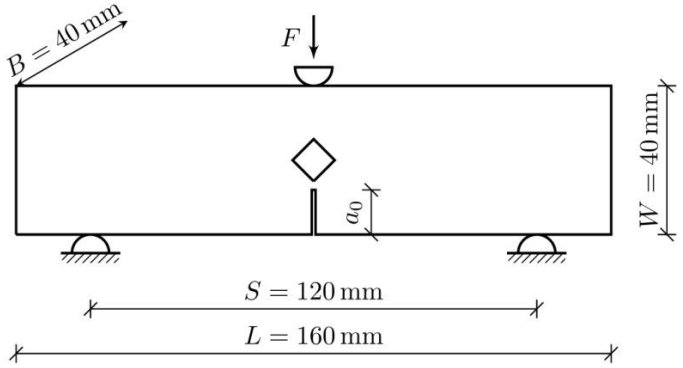

***Figure 1** – Specimen geometry and fracture test configuration*

Acknowledgement This outcome has been achieved with the financial support of the Brno University of Technology under project No. FAST-J-19-6079.

Optimization of autogenously laser beam welded AA 2198 alloy joints

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Abstract

One of the main interests of aircraft industries is to reduce the structural weight of the airframe; this resulted in the development of innovative, lightweight and high-strength 3rd generation Al-Cu-Li alloys. Aluminum alloy AA2198 is a new generation of Al-Cu-Li-alloy that has been developed for fuselage and skin applications in aircraft structures. Among others, laser beam welding (LBW) of AA2198 is a very promising method for joining aircraft materials and structures. Laser beam welded joints are already been exploited in airframe structures, as they provide higher buckling strength and essential lower weight by replacing the respective riveted differential structures.

The effect of laser beam welding process parameters on porosity formation and solidification on cracking for high thickness AA2198 sheets is examined in the present work. Welding process parameters like laser power, welding speed and the resulted linear heat input play a pivotal role in the quality of laser beam welded joints. Therefore, the main objective of the present work is to identify the appropriate process parameters to produce autogenously (without filler wire) welded joints of high quality in absence of cracks and pores. The effect of the welding parameters on the microstructure of the weld was investigated using light optical and scanning electron microscopy. The results showed that full penetration was not achieved for heat inputs less than 50 J/mm. Advanced characterization of geometry of the fusion zone shape (V-shape or rectangular) was performed. It was found that the V-shape fusion welds present lower tensile strength values. To this end, the investigation was focused on the welds with a geometrical factor close to the rectangular shape and the existence of other geometrical defects like underfill. The mechanical behavior of optimal butt-welded joint configurations were investigated by hardness measurements and tensile tests.

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Simulation of a Cementitious Matrix with Carbon Nanostructure Reinforcement

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Abstract

Carbon based nanostructures, such as nanotubes, nanofibers, nanoplatelets, are considered to be a promising reinforcing material for many advanced technological applications. They are often praised as the most effective reinforcement ever discovered, having ~ 100 times the strength of steel. Several experimental efforts have been carried out in order to study their mechanical properties. Most researchers agree that their modulus of Elasticity (E) is at around 1 TPa. Several studies cite the ultimate tensile strength ranging between 120 and 130 GPa. Nevertheless, calculating the mechanical properties of the nanocomposite materials, several limitations occur due to experimental errors, measurement uncertainties, microstructural defects/irregularities and instrument errors, which lead to inaccurate test results.

In the present work, the mechanical properties of CEM-I cementitious matrices reinforced with C-based nanostructures of various forms are simulated, bridging a gap in the international literature. Several experimental test results with varying type and concentration of nano-reinforcement have been performed in order to simulate / estimate the mechanical properties of the nanocomposites with modern computational methods. Several analytical methods have been chosen, e.g. the Mori-Tanaka and multi-step homogenization methods, in order to achieve behaviour simulation of the heterogeneous microstructure as they permit the input of varying orientation inclusions.

The first step in the modelling procedure includes application of the aforementioned analytical methods (Fig. 1). Preparation is almost identical for both methods: the specimen is divided in small domains in order to simulate the shape representation and reinforcement orientation. The selected methodology provides the opportunity to apply the random filler axis algorithm. Since the C-based nanostructures, i.e. the filler of the present research, of real (i.e. non-ideal) materials exhibit random distribution, satisfying results that can exclusively be attained by using the random filler axis algorithm. At this point, the two analytical methods are applied. In the next step, by using the finite element method, a large specimen consisting of many domains will be simulated, in order to calculate the real material's characteristics. The major outcome is the creation of tables / diagrammes that correlate factors such as material characteristics of nano-reinforcement and matrix, volume fraction and dispersion parameters to real composite material predicted properties.

,Electrochemical analysis of the corrosion resistance of aeronautic Al-Cu-Li 2198-T8 alloy in different solutions.

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Abstract

Al-Cu-Li alloys are increasingly used in aerospace applications due to the excellent combination of reduced weight, high specific strength, good fatigue crack growth performance and improved corrosion resistance [1]. Their improved mechanical properties are often attributed to their complex microstructure and especially the precipitation of several strengthening intermetallic (IM) phases. These phases include δ (Al_3Li), θ (Al_2Cu), $T1$ (Al_2CuLi) and S (Al_2CuMg) [2], with the T_1 to be the major strengthening phase. The formation of such IM phases can be accelerated by artificial ageing heat-treatment. However, these precipitates may influence the electrochemical behaviour of such alloys and increase corrosion susceptibility. Corrosion has a deteriorating effect on the aluminium alloys mechanical properties and must be taken into account for the assessment of the structural integrity of aircraft components. Hence the investigation of corrosion mechanisms is of major importance. The corrosion mechanisms of the innovative AL-Cu-Li alloys are not interpreted in the literature. Guerin et al. [3] showed that the fatigue life of AA2050 presented higher reduction percentage at the T34 state than at T84 where intragranular corrosion takes place. Most of the published articles with regard to the newly developed AA2198 alloy are dealing with weldability, plastic deformation [4], fatigue [5] and fracture behaviour aspects [6].

In the present work, the corrosion resistance of AA2198 in T8 temper (under-ageing) will be investigated through electrochemical analysis and compared against T3 temper. The 2xxx aluminium alloys were found to have higher corrosion resistance when artificially aged at certain tempers, such as T6 or T8, than at T3 [7]. Hence, it is of major importance to investigate the corrosion resistance and mechanisms of AA2198 in different tempers. Small rectangular specimens (10 * 20 mm) were machined from aluminium sheets at T8 and T3 tempers of 3.2 mm nominal thickness and exposed to exfoliation corrosion solution (EXCO), 3.5 % NaCl solution as well as to Harrison's solution (3.5% ammonium sulphate, 0.5% NaCl) for different exposure times. Afterwards they were electrochemically tested through electrochemical impedance spectroscopy for the evaluation of corrosion kinetics (corrosion rates) of this alloy. Fracture surfaces were examined using Scanning Electron Microscopy (SEM) to determine the corrosion-induced fracture mechanisms and cross-sections were examined through light optical microscope for the examination of the corrosion morphology.

ACKNOWLEDGEMENT

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, **Seepage and dam deformation analyses with statistical models: support vector regression machine and random forest**

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Abstract Dam monitoring and their safety are an important concern of dam engineers. Seepage collected data are indicators of structure behavior, since seepage is influenced by environ-mental actions, such as air temperature, water temperature, and water level variation, and seepage flow rate is greatly influence by the presence of fractures. Consequently, the analysis of seepage collected data is an important monitoring task, as variations in the seepage can be the alarm for subsequent failures. Seepage data are widely analyzed with statistical models. In this work, we assess the performance of support vector regression machine and random forest models to predict seepage at different points in a case study and identify the most important environmental variables affecting flow rate.

Assessment of computational weld mechanics concepts for estimation of residual stresses in welded box structures

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Abstract In this study different finite element simulation approaches are developed and implemented to study residual stress distribution in a welded box type structure. The component is a vital part in several load carrying structural applications and the residual stresses are important to quantify from a structural integrity point of view. The welded box structures studied have fully penetrated and partially penetrated welds. The thermal history from simulations has been verified with experimental measurements. Tensile residual stresses are observed at the weld root of fully penetrated welded components while compressive residual stresses are estimated at the weld root of partially penetrated welded components. Using rapid dumping method, together with lumping method is able to reduce computational time significantly, compared to thermo-elastic-plastic method.

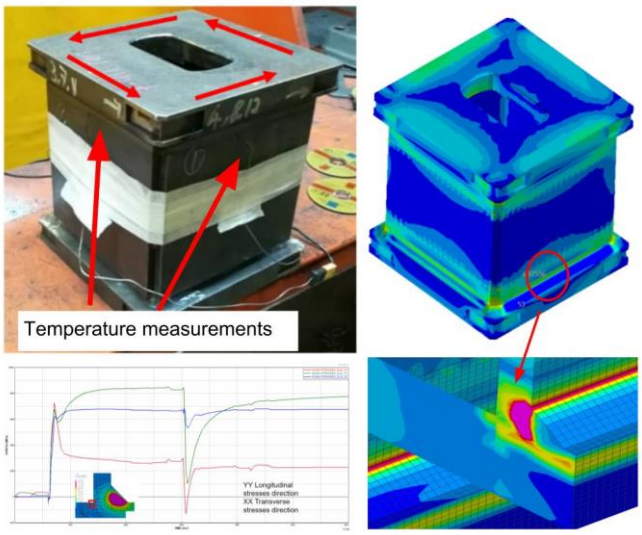

***Figure 1** – Experiments and simulations of welded box type structure*

,Effect of filler wire on the fracture toughness of laser beam welded 2198 joints

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Abstract Many decades ago, aluminum - copper (Al-Cu) 2024 alloy has been widely used in the wings and barrel sections of aircraft structures due to its high damage tolerance capabilities. Innovative aluminum - copper - lithium (Al-Cu-Li) alloys such as 2198, have been recently developed and is supposed to replace aluminum alloy (AA) 2024 in aerospace industry applications. The current trend of the aerospace industries is to further reduce the airframe structural weight and respective manufacturing costs as well as to introduce advanced welding methods as alternative to the classical riveting process for manufacturing of primary aircraft structures. Laser beam welding (LBW) of fuselage structures from aluminum alloys is already established in the aircraft industry for lower fuselage panels since the welded panels provide higher buckling strength and lower weight when compared to the classical riveted designs.

The mechanical behavior of both non-welded and laser beam welded aluminum-lithium alloy 2198 specimens are examined in the present work. Sheets with nominal thickness of 3.2 mm were laser beam butt welded using two different filler wires, namely AA4047 (Al-Si) and AA2319 (Al-Cu), of diameters 1.2 mm and 1.0 mm, respectively. The specimens were machined from the two types of welded sheets, according to the ASTM standards. Some of the specimens were artificially aged before and post to the welding process at 170 ^{o}C and for different ageing times so as to bring the material in all possible ageing conditions.

The specimens were examined with the aid of light optical microscope to investigate the morphology formation of the precipitations on the fusion zone and the heat-affected zone for the different filler materials.

It was shown that the different filler wire plays a critical role on the fracture properties of the welded joint and especially for the fracture toughness. The Al-Cu filler wire responded more accurately to the artificial ageing conditions compared to the respective Al-Si filler wire.

, Verification / Structural Analysis of Industrial Equipment - Identification and characterization of structural damages with hardness tests and microstructural examination – structural verification

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Abstract

The wildfires that tragically occurred in October 2017 in Portugal devastated not only a dense forest and housing area, causing a distortion of our territory and fatalities, but also were responsible for the significant destruction of industrial plants with severe economic and human losses. In this abstract, the possible structural damages resulting from the fire in a dryer were analyzed.

The Industrial Dryer under study performs drying and moisture control processes of wood components. The drying of these wood components is an important process in that the removal of excess water reduces effective weight and improves the mechanical, electrical and thermal properties of the wood, as well as the handling processes. This type of dryer has a water absorption capacity of 2 to 65 t/h. The dryer operation is based on direct heating on a combustion chamber or cogeneration. It bears one or three stages of execution, exit and separation of the product with exit elbow, drop box or cyclone separator, separation of dust with high efficiency cyclones and additional filter systems, gas return system to reduce waste gas volume and power consumption, as well as a last generation control and visualization system.

The structure of the Dryer under study is divided into three parts that make up a total of 20 meters in length. The thickness of the frame (drum) is 15 mm. The mass of all the structure is 89 tons. This abstract focuses in the analysis and identification of the multiple damages on the structure of the dryer using hardness tests and microstructural examination.

, **Computational simulation of a forklift mast - Static and dynamic verification of the operation of a truck with identification of critical voltages and real center of mass**

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Abstract

The forklift mentioned in this report is an electric vehicle adapted for loading, transporting and unloading paper rolls with a specially designed clamp. It´s composed of a three-stage FSW mast with a maximum height of 6.5 meters. The reported failure on the forklift mast was described as premature wear in a specific area, which prevented normal operation of the forklift.

In order to identify the source and cause of the visible damage, static and dynamic analysis were carried out to identify stress concentrations. This study involved several procedures, such as the design and structural verification of the set mass centers, static numerical analysis in ABAQUS and dynamic modeling and simulation with multibody dynamics software.

, Investigation of crane collapse – analysis of fractured bonding elements, center of mass and natural frequencies (dynamics)

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Abstract

In the last ten years, 1125 crane accidents have been reported worldwide, resulting in 780 fatalities. According to reports and published statistics, the causes of crane accidents can be grouped into several categories, one of which is reviewed in this communication.

Tower cranes are commonly used in the construction of buildings, large structures and transportation/movement of heavy loads. Due to their height and unique operating conditions, they are subject to a vast number of loading conditions, both with and without carrying loads or adverse weather conditions. The analysis of the dynamic characteristics of cranes therefore becomes fundamental for the design and effective use of the cranes, as they can be subjected to cyclic loads due to pendulum movements of the suspended loads. The dynamic analysis that has been carried out follows the general basis of several research publications on structures of this kind, consisting on the creation of a 3D model and performing a numerical analysis with the finite element method. This analysis enabled determination of the dynamic characteristics of the crane, natural frequencies and vibration modes, which, in turn, are used to explain the structural behavior when carrying out load movement operations, where cyclic movements identical to those of a gravity pendulum occur.

, Investigation of tank collapse – analysis of support elements collapses, fracture characterization and weld seams, static and dynamic analysis

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Abstract

Storage tanks or reservoirs, are containers for storing fluids at atmospheric or higher pressures. Design and manufacture of pressure tanks follows specific requirements, depending on the type of fluid to be stored, storage conditions, purpose and location. For storage of fluids such as petroleum and its derivatives, API 650 code for the construction of reservoirs that can vary from 2 m in diameter to 50 m or more is usually followed.

Regular and periodic maintenance, checking and cleaning of the structures and equipment for storing the products are essential factors to maintain the durability of the tank, preventing stored products degradation or spillage.

However, according to statistical data there have been more than 242 storage tank accidents worldwide in the last 40 years. About 30% of these accidents took place in non-oil industries and were caused by factors such as fire, explosion, lightning, human error, poor construction and lack of maintenance. It can also be noted that in 242 accidents, 31 were directly related to fatigue and fracture.

The accident reported in this communication occurred with a reservoir of 2765 mm in diameter and 6052 mm in height, used in the food industry for storing vegetable oil. Analysis of the failure has shown that the feet supports of the reservoir had collapsed.

Based on the identification of the deformed and damaged area, technical drawings and the analysis of the weld beads at the bottom of the reservoir, the root cause of the accident was determined and verified.

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Friction stir welding of polymers: recent developments

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Abstract

The main objective of this work was to develop a new friction stir welding conceptual solution to weld polymeric materials. For this purpose, there are various aspects that needed to be addressed carefully. In order to demonstrate the flexibility of the developed system, welding was performed in two commonly used configurations in industry: butt-joint and lap-joint. The main focus of this study was to develop a welding tool without the use of an additional heat source, capable of welding different materials using higher welding speed than the ones in the literature. The final tool design was able to generate frictional heat up to 400ºC and weld 10 times faster than the initial tool design, producing joints with a tensile strength within 97% of the parent material's tensile strength. A sensitized clamping device was developed to monitor all the generated forces in three pre-defined directions during the welding process, and support the evaluation of the weld quality as a function of load output. With the developed clamping device, it was possible to find the relationship between the vertical load and the weld quality, even when using a position control approach. Moreover, it was claimed that unlike metallic materials, polymer FSW is not a solid-state welding process, since the welding temperature will reach above the parent materials' melting points. For Polymer FSW, welding tool is the most important factor, and all the parameters are under influence of the tool design and its geometry. Basically, with the appropriate tool design and judicious parameters, FSW is capable of producing strong welds with good mechanical properties to weld a wide range of similar/dissimilar polymeric materials in different configurations.

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Friction stir spot riveting of thermoplastic composites

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Abstract

Joining methods of lightweight materials, particularly polymers and composites, are becoming progressively important in the manufacture of lightweight structures for engineering applications. Glass-fiber-reinforced polymer (GFRP) and carbon-fiber-reinforced polymer (CFRP) composites are the most common thermoplastic composites that are being used in lightweight structures. In this study, an innovative spot welding tool was developed, which is capable of spot weld similar/dissimilar polymers and composites. The developed tool consists of a stationary fixture that clamps the base materials rigidly in the desired position and a consumable probe that penetrates into the base material under an axial force. The consumable probe or the filler material is located inside a rotating shaft made of brass, which is surrounded by a stationary copper sleeve to generate frictional heat during the plunging stage. The top and the bottom of the fixture is designed in a way that guide the plasticized filler material to create the riveting effect under the axial force. The main benefit of this newly developed welding tool is the combination of the friction stir spot welding method with riveting on the sides. Using this tool, dissimilar polymers and identical short carbon fiber thermoplastic were welded successfully. The produced joints showed a promising results as it stirs the base materials with the rotating filler, and the rivets on the two sides create a secondary bonding condition, which enhanced the joint efficiency. This welding technique can be developed into a portable device to weld/repair thermoplastic based composite and polymer structures.

,3D Laser Scanning System for Geometry Acquisition on a Railway Tunnel

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Abstract

In this research, a 40-m-long shallow railway rock tunnel known as "Monte Seco tunnel" located at Vitória-Minas Railway in Brazil is studied. It has been scanned by a 3D Terrestrial Laser Scanning (TLS) instrumentation and its geometry was reconstructed as a point cloud. The obtained shape lacked geometrical details in some regions due to geometry complexity and irregularities. Then, a small-scale model was built through additive manufacturing in order to be used in laboratory tests. A demonstrator was developed relying on a 3D laser scanning system (LSS), encompassing a circular laser and a camera, to acquire the tunnel profile. The studied tunnel model was compressively loaded from the exterior wall and its deformation was monitored by a 3D Digital Image Correlation (DIC) system. Promising results have been accomplished and the achieved tunnel's point cloud matched the expected geometry with minimal occlusions. Owing to the successful results obtained on the geometry acquisition, a 3D LSS system to be operated in the real environment was outlined.

Keywords: Railway tunnel, 3D Laser scanning system, Shape acquisition, DIC.

Geometry Acquisition and 3D Modelling of a Wind Tower using a 3D Laser Scanning Technology

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Abstract

This work aims at acquiring the interior shape of wind towers by means of a 3D Laser Scanning System. Typically, towers are made of S355J0 steel sheets and their fabrication consists of roll bonding and welding of abutted rolled sheets. This task is typically carried out by welding robots moving though the tower structure. The developed setup consists of a camera and a circular laser module mounted on the welding robot's arm moving through the tower with a constant linear velocity. The deployed system assists in examining the tower's interior surface, making it possible to obtain its 3D profile. It will therefore be beneficial to monitor the geometric changes which occur over the welding process due to the residual stress and the tower's own weight. Encouraging results have been achieved in the characterization of the tower's geometry, contributing to the assessment of the robustness and accuracy of the deployed 3D laser scanning system.

Keyword: Wind towers, 3D laser scanning, Image processing, Inspection.

, Design of an Automated Inspection System to Monitor Defects in Railway tunnels

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Abstract

This contribution aims to establish an automated inspection method to monitor defects on railway tunnels and build a demonstrator for this procedure. Monitoring and detecting defects have been principally manual time-consuming procedures, therefore, an automated designed system will increase the standards and quality. The present research relies on a 3D laser scanning technique to study the inspection of the tunnel degradation, particularly in terms of structural integrity. To assess the applicability and accuracy of the deployed 3D laser system, the implementation of a model prototype on a scaled tunnel is proposed for the laboratory experiments. Local defects and geometry changes could be detected by comparing obtained profiles. Thereby, post-processing analysis is performed to measure internal variables such as displacement and strain fields with an optical measuring tool developed based on 3D Digital Image Correlation (DIC). In conclusion, encouraging results are presented for the evaluation of the tunnel conditions and the monitoring of the tunnel profile in static scanning mode, and DIC data that shows the displacement field progress of an introduced structural defect is presented.

Keywords: Railway tunnel inspection, Defect detection, 3D Laser scanner, DIC,

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Ductile Failure Prediction of an Al-Mg Alloy: Experimental and Computational Validation

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Abstract

The emergence of reliable techniques to predict the failure mechanism of the engineering structures in automotive and aeronautic industries in particular sheet metal forming promises to underpin a novel advance in materials research. In this regard, Al-Mg alloys deliver the largest formability range. This study aims at determining the mechanical properties of an AA5352 aluminum alloy, using Digital Image Correlation, DIC. Thus, tensile sheet specimens manufactured from the corresponding alloy are mechanically tested under a uniaxial condition and deformation fields are monitored. Considering the force/displacement response and stress/strain curves, the material Poisson coefficient, Young's modulus and anisotropy coefficient in the transverse direction are characterized by the experimental DIC data. It aims to obtain accurate and reliable mechanical properties to be considered in the future processing analyses. Numerically, adopting the experimentally obtained material properties, the Gurson-Tvergaard-Needleman (GTN) damage model is implemented using finite element method – FEM– formulation to forecast the ductile fracture performance of the tested AA5352 sheet. The predicted results are then compared to the experimental DIC solution verifying good agreement with the force/displacement response and the deformation fields. Overall, the acquired numerical results imply that the GTN fracture criterion is capable to render an accurate prediction upon a high stress triaxiality state.

Keywords: DIC, GTN, FEM, Ductile Damage, Experimental mechanics.

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Application of spline interpolation to speckle shearography measurements for damage identification

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Abstract This paper aims to explore a new technique for structural damage identification using cubic spline interpolation. The method is based on the interpolation of modal rotations measured with speckle shearography. In order to locate the damaged areas, we make use of the analytical derivative of the cubic spline function to compute the modal curvature, which is known to be very sensitive to damage. A comprehensive parametric study of the spatial sampling interval is carried out to find its influence on noise filtering. Furthermore, the identification quality dependency on the mode shape and respective noise is also examined. The results obtained with the proposed method show the consistency of the localizations. Additionally, the challenging tasks of identifying small and multiple damage (Figure 1) are tackled, yielding a good performance.

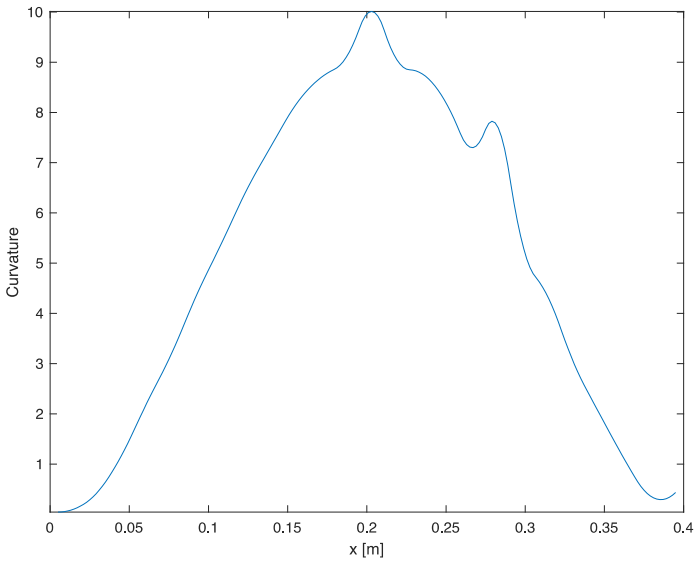

***Figure 1** – Example of multiple damage identification using the first mode*

, Environmental Testing of FBG Sensor System for Structural Health Monitoring of Building and Transport Structures

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Abstract Recently, there has been an increased interest in structural health monitoring (SHM) of building and transport structures. Standard strain gauges placed on a beam surface are mostly used to monitor the mechanical stresses of timber or concrete structures. However, these sensors are susceptible to mechanical damage, electromagnetic interference or negative influences of the measured data during the measurement. The fibre optic sensor system offers a more suitable and reliable solution – the sensors can be integrated directly into the load bearing structure during its production and thus protected by the construction material against ambient environmental conditions. First part of this paper presents series of environmental tests of measuring system based on Fibre Bragg Grating principle performed from 2016 to 2018 in the climate chamber. The chamber can generate defined humidity and/or temperature cycles, which can simulate the behaviour of the structure under real environmental conditions. The tested fibre optic sensor system is suitable for load bearing timber (glued laminated timber beams) and concrete structures. In the second part of this paper, mechanical loading tests of glued laminated timber beam with integrated fiber optic sensors performed in 2016, 2017 and 2018 are presented. The article describes the design of test cycles, gives the results of testing, and is concluded with the discussion of given results together with the outline of the future research directions.

, Stability Analysis of Compression Members on Elastic Supports

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Abstract The part of the large parametric study focused on the stability behaviour of compression single members and the member structures with various loadings and boundary conditions is presented here. This part relates to the stability analysis of the compression member on elastic springs. The span of the member L = nℓ, where ℓ is the length of the panel which equals to the distance between the neighbouring elastic springs. The members under investigation have seven various numbers of the panels n = 2, 3, 4, 5, 6, 7 and ∞. The members have uniform bending rigidity EI, uniform normal force N and (n – 1) elastic springs with equal spring stiffness C_w. The results are presented in the form of diagrams. The curves of diagrams were replaced by the straight lines to be able derived approximate formulae for calculation of the critical force. It is shown that approximate formulae give the values of the critical forces $F_{cr.a}$ which differ from diagram values F_{cr} less than 3.3 %, being slightly on the safe side. The values of the critical forces F_{cr} obtained from the solution of the stability equation are verified by comparisons with results $F_{cr.IQ}$ of the computer program IQ 100. Excellent agreement is achieved between $F_{cr.IQ}$ and F_{cr}. The presented solution of the compression member on elastic springs may be used also for the calculation of the critical force of the compression member on elastic foundation. The solution given in the paper creates scientific background needed in the design of the semi-through bridge trusses.

The obtained diagrams will be used in the following document which is now in preparation: CEN/TR 1993-1-103 Eurocode 3 – Design of Steel Structures – Part 1-103: Elastic Critical Buckling of Members. The results of the parametric study are compared with results of other authors and verified by several numerical examples.

Table 1. Comparisons of the diagram values F_{cr}, approximate values $F_{cr.a}$ and exact values $F_{cr.IQ}$

n	C_w [kN/m]	F_{cr} [kN]	$F_{cr.a}$ [kN]	Difference between F_{cr} and $F_{cr.a}$	$F_{cr.IQ}$ [kN]
2	58.66	186.73	182.374	- 2.73 %	187.50
3	99.732	231.603	223.707	- 3.324 %	231.40
4	134.931	260.553	256.282	- 1.841 %	261.09
5	74.505	202.652	200.398	- 1.447 %	203.34
6	99.732	231.603	228.435	- 1.282 %	231.40
7	134.931	260.553	257.235	- 0.918 %	259.62

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An interactive cloud-based fatigue analysis tool

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Abstract An interactive with easy four-steps, cloud-based fatigue analysis and life prediction tool is presented. Users around the globe may access it via Internet by means of multiple platforms such as desktop and laptop computers, tablets and/or smart-phones. It is a selfexplanatory education software, which is aimed also to assist a designer in a pre-prototype stage in fatigue life estimation of smooth or notched parts subjected to constant amplitude, block loading, and spectrum loading histories. For spectrum amplitude loading a dedicated spectrum software package is provided, which is essential for a potential clean-up and/or desired modifications of a raw spectrum data. Subsequently, a rainflow method is utilized and the corresponding hysteresis loops at the notch-root or critical "hot spot" location are determined and plotted.

For notched components, a generalized Neuber's rule suitable for numerical application is utilized and discussed. It is shown, that the so called Neuber's "master" curve, involved in such analysis (shown in Fig. 1) is unique and is only material dependent. The Neuber's "master" curve is interactive and is applicable for both monotonic and cyclic loading situations. Examples of applications of the proposed method are presented for a constant, block, and spectrum loading situations. Associated fatigue life predictions are illustrated using stress, strain, and stress/strain approaches.

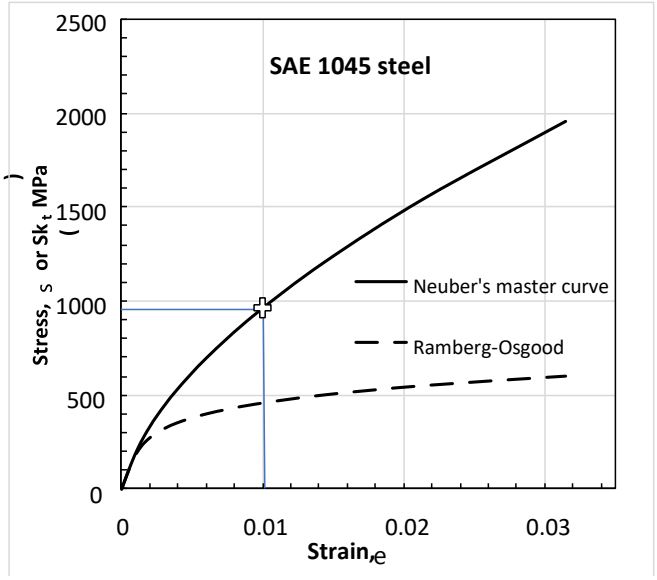

Figure 1 *Ramberg-Osgood and Neuber's "master" curve.*

An estimation of Ramberg-Osgood constants for materials with and without Luder's strain using yield and ultimate strengths

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Abstract Tensile engineering stress-strain curves for metallic materials typically show two different behaviors *viz*. with Luder's strain and without Luder's strain. Recently, Kamaya [2016] proposed a method to estimate the true stress-strain curves based on yield and ultimate strengths. This method however, is not accurate enough for materials exhibiting Luder's strain in their stress-strain behavior. Hence, a new procedure for the materials exhibiting Luder's strain is proposed. This new method uses plastic strain value corresponding to Luder's strain along with yield strength and ultimate tensile strength to estimate constants in the Ramberg-Osgood (R-O) type of true stress-true strain relationship. The proposed approach was applied to 17 different materials with and without Luder's strain to validate the proposed estimation. In addition, an inverse method for assessing an apparent ultimate tensile stress (stress at point of zero slope) for materials with low ductility due to quenching or carburizing is suggested.

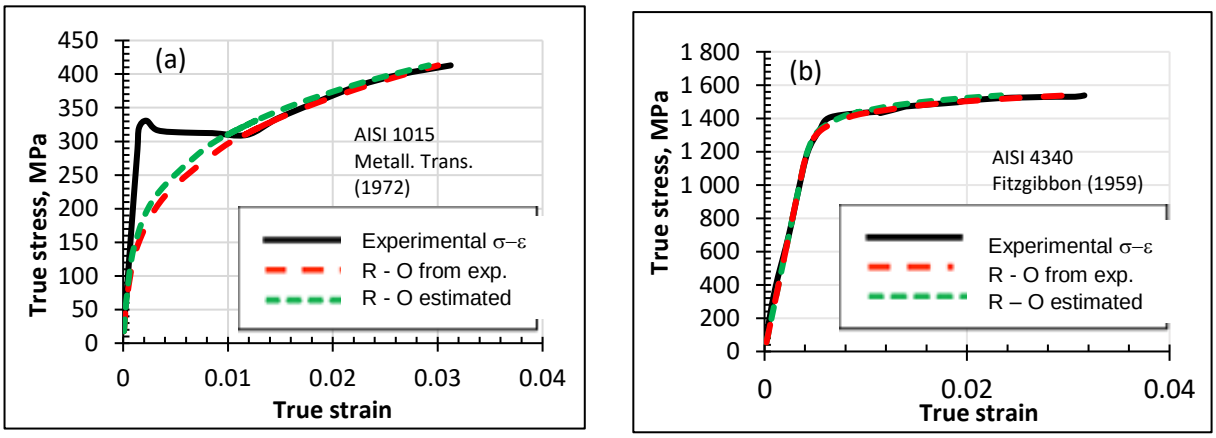

Figure 1 *Comparison of experimental stress-strain curve with the Ramberg-Osgood relation from experimental data and estimated for materials (a) exhibiting Luder's strain and (b) without Luder's strain.*

Structural Integrity Analysis and Life Estimation of a Gas Turbine Bladed-Disc

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Abstract Turbine blades and bladed discs are critical components in an aero-engine which are subjected to severe conditions of high temperature and pressure. These conditions cause high levels of stress leading to crack formation and subsequent failure in service. In this work, an attempt has been made to investigate the influence of crack on vibration parameters of a typical aero-engine gas turbine blade and a life assessment approach for turbine blade and bladed disc is also described. Initial investigations are carried out on idealizations involving cantilever beams with uniform cross-section; the procedures are then extended to free standing turbine blades with asymmetric aero foil cross section mounted on turbine bladed disc. Dynamic characteristics of the blade are estimated and free vibrations analyses have been carried out for healthy blade and ones with crack of different sizes. Influence of crack size on natural frequencies and mode shapes is studied. Results show a difference of less than 1% in frequency for cracks less than 1mm in length; for larger crack lengths the frequency shifts are higher. The analytical results are compared with experimental tests on a Laser Doppler Vibrometer set-up. Subsequently, forced vibration analysis has been performed and a methodology has been developed, using Lazan's law to extract modal damping ratios from the strain energies of the blade under nozzle excitation pressure fluctuations. The modal damping ratios thus obtained are indicative the energy dissipation in the component under stress conditions. The possibility of employing these modal damping ratios as indicators for the presence of cracks / defects is outlined. Damping ratio was calculated for the first two modes of the cantilevered turbine blade. These ratios show a difference of the order of 5.2 % between healthy and cracked blades for the second mode. This observation leads to a conclusion that modal damping can be a viable parameter with good correlation with blade structural integrity.

Numerical analysis of shear crack propagation in a concrete beam without transverse reinforcement

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Abstract Crack formation and growth in reinforced concrete members is in many cases the cause of the collapse of technical structures. Such serious failures impair the structural behavior and can also damage property and persons. An intensive investigation of the crack propagation is indispensable. Numerical methods are being developed to analyze crack growth in an element and to detect fracture failure at an early stage. For reinforced concrete components, however, further research and action is required in the analysis of shear cracks. This paper presents numerical simulations and continuum mechanical modeling of bending shear crack propagation in a three-dimensional reinforced concrete beam without transverse reinforcement. The analysis will provide further understanding of crack growth and redistribution of inner forces in concrete members. As numerical method to map discrete cracks the extended finite element method (XFEM) is applied. The crack propagation is compared with the smeared crack approach using concrete damage plasticity. For validation, the crack patterns of real experiments are compared with the results of the different finite element models. The evaluation is based on single span beams under bending. With the analysis it is possible to predict the fracture behavior of concrete members.

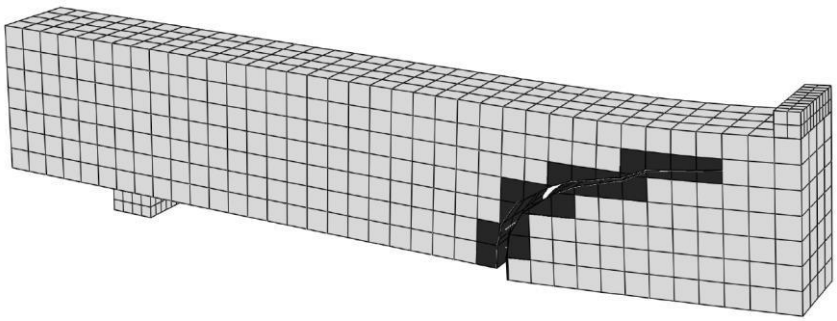

Figure 1 – *Crack propagation in a concrete beam by using XFEM analysis of ABAQUS*

, Enhanced algorithm for damage location on composite material

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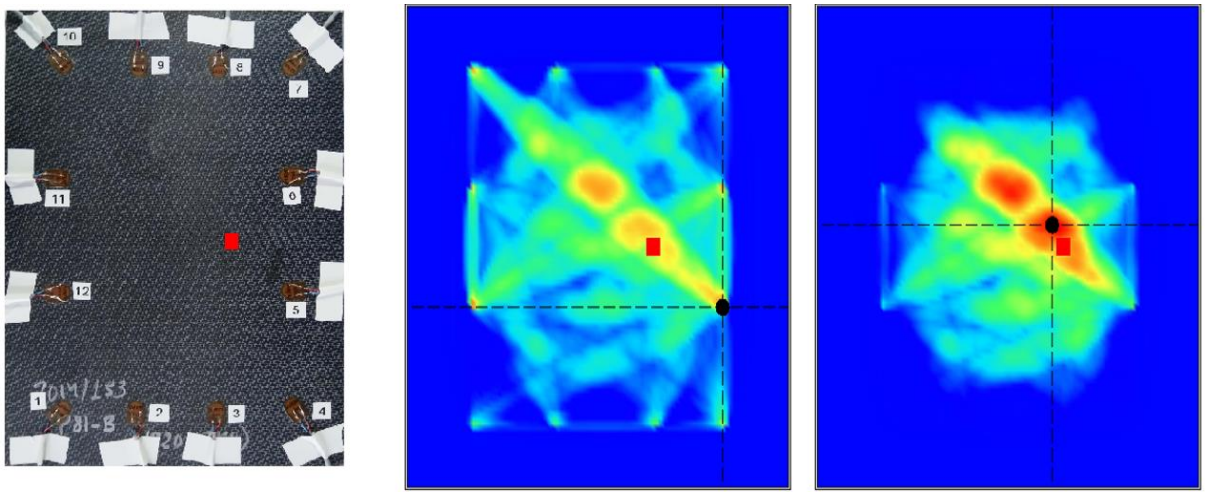
Abstract: Structural Health Monitoring (SHM) of aircraft structures, which are manufactured increasingly using composite materials, is a technique which aims to improve reliability and to reduce maintenance. Composite materials present several difficulties for the location of damages due to their mechanical properties (anisotropy, wave propagation, stiffness, etc.).

In this study, the RAPID (Reconstruction Algorithm for Probabilistic Inspection of Damage) algorithm has been used to detect and locate damages in small surface composite material samples, using Lamb waves generated and recorded with piezoelectric transducers (PZT). The algorithm was applied to data from the pristine and current state structures, and only current state data (baseline free method).

Some of these tests provide inaccurate predictions of the damages location, caused by masking under the influence of path intersection points among transducers. The new proposal for the enhanced algorithm solves this point performing a geometrical modification of the standard RAPID algorithm.



(a) **(b)** **(c)**

Figure 1 – *(a) Composite thermoplastic with damage (red square). (b) Predicted location provided by standard RAPID (black point). (c) Predicted location provided by enhanced RAPID (black point).*

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Hydraulic tube inspection of a Boeing aircraft

Freitas, M., Infante, V.

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Abstract Several failure analysis of hydraulic system have been reported on literature, therefore for safety reasons the root causes of these failures must be well identified in order to avoid future accidents. This article describes an inspection of the failure of a hydraulic tube of a commercial aircraft. The developed study comes following an accident occurred in which a lack of oil was observed during service. The failure occurred in the transition zone between hydraulic hose and the connection components of the hydraulic system. In order to determine the causes of the failure, a material analysis was performed, followed by a detailed study of the fracture's surface both visually and using optical and scanning electron microscopes. From the analysis of the observations made it was concluded that the damage suffered by the component was promoted by an overload imposed on the material that caused the fracture of the inner hose of the flexible hydraulic tube and the localized plastic deformation of the metallic mesh in the zone of crimping promoting the loss of tightness of the component.

, Study of the mechanical strength of the wings of a domestic frying pan

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Abstract This paper presents a detailed analysis of the failure of a domestic frying pan. The failure occurred in the wings of the pan. The main objective of the study was to obtain the materials resistance in bending of the wings when subjected to the more severe conditions of temperature in service defined by the manufacturer. The study was divided in three phases: 1st phase - The body of the frying pan, not insulated thermally, was subjected to the amount of heat necessary for the temperature of the body reach 210° C uniformly. As soon as the above condition is established, the frying pan was remain for one hour in that condition; 2nd phase - The wings of the frying pan will simultaneously be subjected to a load of increasing value, which imposes a bending effort, in order to simulate the procedure of removing the frying pan from the heat source; When any of the wings fracture or when it is found that the connection between them and the body of the frying pan shows signs of not guaranteeing the normal handling of the object under safe conditions, the value of the load that caused the fracture was recorded; 3rd phase – Repetition of 1st and 2nd phase using a new frying pan. During the analysis it was observed that no significant change in the morphology of the wings of the frying pans when subjected to temperatures close to 210 ° C. The frying pan materials supported about 500 N (~ 51 kg) before the fracture of one of the wings when the frying pan was subjected to a three-point bending test to simulate the procedure of removing the frying pan from the heat source.

, Optimization of the Homogenization Characterization of Thin Hybrid Composites

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Abstract Hybrid composites are becoming increasingly important in high-technology applications, particularly in the aeronautical industry. Actually, hybrid composites may offer an effective solution for increasing the toughness of a composite material. Besides that, hybrid composites can have high specific stiffness, high specific strength, low density, and reduced cost.

Manufacturing process of a thin hybrid composite could be complex, and thickness error could influence elastic properties of composite material. In fact, matrix weight has more variability in thin composites. Elastic properties can be computed using a homogenization theory based on a representative volume element (RVE) approach, which assumes that the composite material is locally formed by the spatial repetition of very small microstructures. However, different thickness values due to different matrix weights causes a high variability composite elastic properties. This variability can cause some uncertainty and errors in thin composites design.

In this work, homogenization elastic properties characterization is performed for a thickness range close to the desired one. The composites considered have a total of 4 plies of carbon and glass fibers. These composite layers were manufactured, the thickness was measured, and tests were performed considering a combined loading of bending and torsion. A numerical simulation, using Abaqus, was also performed in order to compare experimental tests with numerical ones. With this comparative model is possible to optimize the homogenization process in order to have the correct elastic properties considering thickness variability. In this way, a sensitive analysis is also performed and manufactured plies can be rejected due to thickness values variability.

By design, composite plates are usually aimed to have a constant thickness value. However, thin plates can have high thickness variability due to manufacturing process. Preliminary results, considering homogenized elastic properties, experimental tests and numerical analysis, conclude that thickness variability has a significant influence in thin composite elastic properties.

Keywords: Hybrid composites, carbon and glass fibers, homogenization, optimization

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Numerical Simulations of Fatigue Crack Growth in a Steam Turbine Rotor Blade Groove

Jiří KUŽELKA[1], Martin NESLÁDEK[1], Maxim LUTOVINOV[1], Josef JURENKA[1], Milan RŮŽIČKA[1], Martin RUND[2], Petr MĚŠŤÁNEK[3]

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Abstract With increasing share of renewable energy sources in the electricity production strict demands are placed on fossil power plants that have to cover the power shortages more frequently. Increasing number of steam turbine (ST) start-ups and shutdowns, as well as requirements on higher ramping of operating conditions, has detrimental effect on the overall lifetime of ST components. In the ST design process, this situation has to be dealt by applying advanced prediction methodologies handling the thermo-mechanical fatigue mechanism, for instance. On the other hand, in the case of currently operating STs, regular inspection and maintenance schedule as well as technologies for turbine operation control have to be reconsidered or newly developed. To cope with these challenges, the international consortium of energetic turbine producers and research institutes initiated the TURBO-REFLEX project funded by EU's H2020 program. One of the principal aims of the project is development of a damage tolerance approach suitable for scheduling the ST rotor maintenance. Decisive factors in this effort are ST rotor operating conditions, material fracture properties and geometry that constitute the crack initiation site and crack growth rate and direction – *Fig. 1*. This forms a complex task that has to be handled numerically by using an FE-based code accompanied by in-house scripts for detecting the most probable way of crack propagation. In our contribution we are about to present the adopted approach and results that have been achieved.

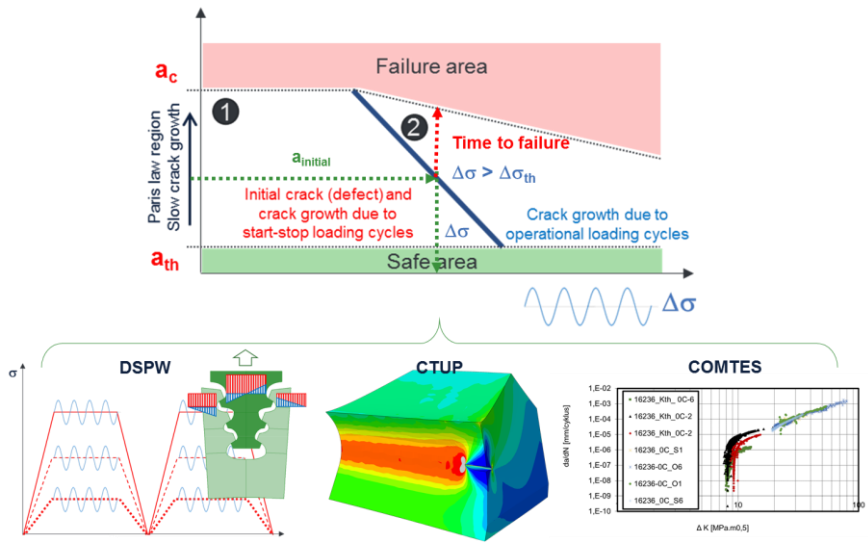

Figure 1 – *A general scheme showing combination of individual analytical aspects in development of the damage tolerance map applicable to ST rotors.*

, Effect of Heat Treatment on Additively Manufactured AISI 18Ni300 Steel using Selective Laser Melting

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Abstract Additive manufacturing (AM) technology allows the fabrication of complex parts, offering great flexibility with minimum scrap compare to subtractive manufacturing. Selective Laser Melting (SLM), a type of AM technique, conducts a layer by layer fabrication process of metallic powders for low-volume high performance metallic components, targeting multiple industries. However, the reliability of SLM materials particularly in aerospace industry is an ongoing concern, requiring additional considerations such as dynamic mechanical characteristics of the components. This work investigates the strain-rate sensitivity of maraging steel AISI 18Ni300 manufactured using SLM process. Metal powders were fused into test coupons of 2mm thicknesses in order to examine the strain rate sensitivity of the fabricated material. Dynamic tension tests were carried out using Split Hopkinson Tension Bar (SHTB) apparatus in conjunction with Digital Image Correlation (DIC) technique. Comparative analysis was conducted between in-built and heat treated SLM materials to study the effect of residual stresses subjected to wide range of strain rates.

, Structural integrity and durability of polymer composites: Achievements and challenges

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Abstract Modern composites, made up of carbon fibres and toughened epoxy resins, are lighter/stiffer/stronger and increase fuel efficiency in aircraft, compared with the aluminium currently used. They have been used in the Airbus A380 super jumbo, the first fully double-decked passenger jet (with more than 550 seats, but certified for 853 passengers) that took its first commercial flight in 2007, the Boeing 787 'Dreamliner' aircraft and the A350 that came into service in 2015. The primary structure, including the wing and fuselage, of the B787 200-seater passenger jet is built mostly from composite materials and is advertised to be 20% more fuel efficient than current commercial planes with almost 60% more cargo space than the Airbus A300-200. It is accepted that modern composite systems offer a variety of advantages, however, affordability (reduced acquisition and direct operating costs, while maintaining or enhancing safety) is the key to survival in aerospace manufacturing, whether civil or military. Therefore current research effort is devoted to analysis and computational simulation of the manufacturing and assembly process as well as the simulation of the long term performance of the structure, since these are intimately connected.

In this talk, applications of modern composite systems will be discussed and achievements, but also challenges and limitations, in the non-destructive characterisation (microscopic) and damage modelling of such material systems with some thoughts on future needs, developments and prospects for novel materials (graphene based composites, 3D woven architectures) and processes, structural health monitoring (SHM), fatigue life, maintenance and repair

Professor Constantinos Soutis FREng is holding a Chair in Aerospace Engineering, and he is the Director of the Aerospace Research Institute and Director of the Northwest Composites Centre at the University of Manchester, UK. Prior to this, he has held academic positions at the University of Sheffield, Imperial College London, University of Leicester, University of Cambridge and visiting professorial posts at Massachusetts Institute of Technology (MIT) and University of South Carolina, USA. He is a Fellow of the Royal Academy of Engineering and leading authority on mechanics and failure of composites, with significant contributions on modelling damage mechanisms and structural health monitoring using low frequency Lamb waves techniques. His industrial research and engineering experience includes work with the Structural Materials Centre of the British Defence Evaluation & Research Agency (visiting research fellow, 1995-2001), QinetiQ (Trusted Expert, 2001-2003), Cambridge Consultants, Dowty Propellers, Cytec Materials Engineering and ABB Research in Switzerland. Professor Soutis is the author or co-author of over 400 archived articles, which include more than 250 ISI listed journal papers; some 30 PhD students have qualified under his supervision and guidance. Professor Soutis is the Deputy Editor of Applied Composite Materials Journal, an Associate Editor of the RAeS Aeronautical Journal and served on the International Journal of SHM.

, The Latest Development of Bio-sourced Composites for GREEN Aviation

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The University of Nottingham Ningbo China

Abstract After an overview on biocomposite materials developed by an internationally joint project, ECO-CAMPASS (Ecological and Multifunctional Composites for Application in Aircraft Interior and Secondary Structures, 2016-2019), roxin-sourced epoxies and the composites are introduced as a successful output of the project. The composites are jointly developed by a close cooperation of ACC with the Ningbo Institute of Materials and Technology Engineering (NIMTE). The composites show promising mechanical properties and processing ease in autoclave and RTM, providing thus a suitable alternative materials for interiors and non-structural applications. However, the interlaminar toughness and impact damage resistance of them are not sufficient if comparing with the existing petroleum-sourced polymer matrix composites used in aviation.

To improve the toughness of the GREEN composites, Ex-situ technology has been used to modify the roxin-sourced composites, either by reaction-induced spinodal phase decomposition and inversion mechanism, as well as by Vecro-like co-continuous toughening mechanism. The preliminary results exhibit that both the interlaminar fracture toughness's and the Compression After Impact (CAI) properties have been significantly improved, whereas the most in-plane mechanical properties and processing characteristics remain less affected. It can be expected that the bio-sourced composites can be used not only in secondary, but also in primary aerospace structures as a GREEN alternative composites.

Professor Dr.-Ing. Xiaosu Yi, University of Nottingham Ningbo China (UNNC) and Aviation Industry of China (AVIC). He received his PhD (Dr.-Ing.) degree from the Faculty of Maschinenbau of University of Paderborn, Germany in 1986. Prof. Yi is actively involved in R&D of composite materials in academia and industry over 30 years.

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Progress in Solid State Joining of Metals and Alloys

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Abstract In this overview, a new solid-state joining method for metals and alloys is presented, where the best features of gas metal arc welding, friction stir welding and cold pressure welding are combined. The invention, which is known as the Hybrid Metal Extrusion & Bonding (HYB) process, utilizes continuous extrusion as a technique to squeeze the aluminum filler material into the groove between the two plates to be joined under high pressure to achieve metallic bonding. Originally, the idea was to use the HYB process for simple butt joining of aluminum plates and profiles. However, over the years it has evolved into a multi-functional joining process handling a wide range of different joint configurations (butt, fillet and slot welds) and base metal combinations (Al, Fe, Ti and Cu). At present, up to four different metals can be joined together in one pass using the HYB PinPoint extruder and AA6082 as filler wire.

Professor Øystein Grong (born 1956), received his PhD degree from the Norwegian University of Science and Technology (NTNU) in 1983. He has worked as a Research Scientist at the Norwegian Defence Research Establishment, Kjeller, Norway and as a Visiting Research Professor at Colorado School of Mines, Golden, Colorado and National Institute of Standards and Technology, Boulder, Colorado (USA). He was appointed Professor of Metallurgy at the Norwegian University of Science and Technology in 1987 by the King of Norway and the Prime Minister. Professor Grong has a broad interest and research experience in materials in general and microstructural modelling in particular. A significant part of this work is related to thermomechanical processing and welding of metals and alloys. He has educated 58 MSc and 22 PhD students and written 264 publications, including 94 major scientific papers in referred international journals. He is also the author of the well-reputed textbook Metallurgical Modelling of Welding, which formerly was ranked among the top ten books (best sellers) from the Institute of Materials in London. In addition, he holds seven patents and has received four international awards and one prestigious national award for his scientific contributions. Professor Grong is currently self-employed through his own company and fully engaged in the development of the Hybrid Metal Extrusion & Bonding (HYB) process together with industry partners and colleagues at the Department of Mechanical and Industrial Engineering, NTNU.

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Micromechanical Modelling of Weldment Cracking

Aleksandar Sedmak

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Abstract. Local approach to ductile fracture has been used to analyse crack initiation and propagation in welded joints made of high strength low alloyed steel. Complete Gurson micromechanical model was applied to calculate J integral vs. crack length (J-R curves) for different locations of a crack, weld metal (WM) and heat-affected-zone (HAZ), both fine grain (FG) and coarse grain (CG) subzones. Two different geometries were analysed, 3PB specimen and tensile panel (TP), the first one as 2D, and the later one as 3D problem. Numerical results were compared with the experimental ones to verify the model, Fig. 1 and enable detailed analysis of different effects, including constraint due to material heterogeneity and geometry, i.e. stress triaxiality, Fig. 2 & 3. It was concluded that material heterogeneity effect, although not very strong, may not be reduced just to ratio of yield strengths of base metal and weld metal, but rather, the hardening effect has to be taken into account, whereas geometry produces very strong effect due to constraint phenomena, especially with 3PB specimens.

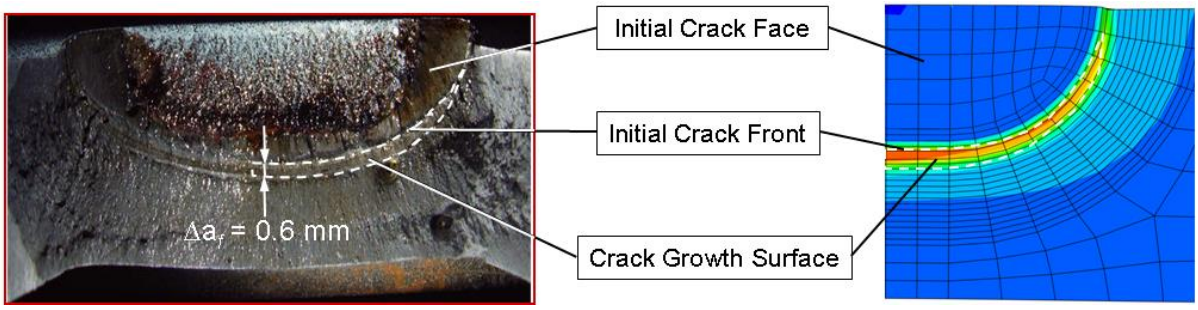

Figure 1 - *Comparison between experimental and numerical fracture surfaces for WM*

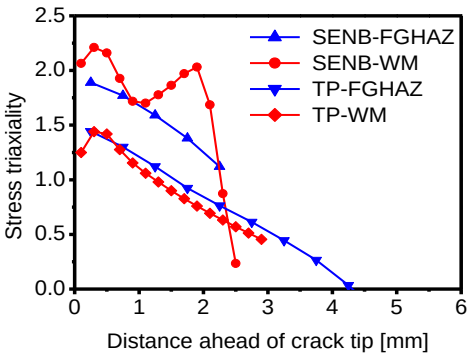

Figure 2 – *Stress triaxiality ahead of crack tip*

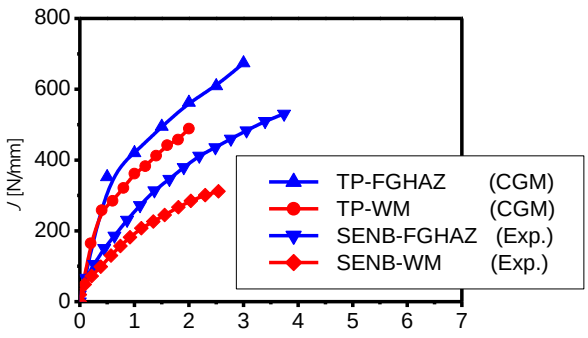

Figure 3 *– J-R curves*

Professor Dr. Aleksandar Sedmak, graduated from the Faculty of Mechanical Engineering University of Belgrade in 1978, and received his D.Sc. from the Faculty of Mathematics, dept. of Mechanics, University of Belgrade, 1988. Since 1990 assistant professor, and since 2001 full professor at the Faculty of Mechanical Engineering University of Belgrade. Visiting professor at Drexel Univeristy, USA, 1999-2002. Assistant Minister for Science and Technology Development 2003-2006. Vice-rector for international cooperation, University of Belgrade, 2006-2009. Director of Innovation Center of the Faculty of Mechanical Engineering in Belgrade since 2006. Main topics of research and teaching are Engineering Materials, Welding, Numerical Methods, Fracture Mechanics and Structural Integrity. Advisor for more than 50 D.Sc. thesis, published several textbooks. He published 120 papers in WoS journals with more than 500 citations, 120 papers in other journals, mono-graphs and conferences, total more than 750 references, mostly in Fracture Mechanics, Welding and Material Science field. He is the President of Serbian Structural Integrity and Life Society, Editor-in-chief of Structural Integrity and Life Journal, and the Vice-president of European Structural Integ-rity Society (ESIS), since 2014. He is member of editor boards and reviewer of a number of prominent world journals in Fracture Mechanics, and the Chairman of European Conference on Fracture (ECF22), Belgrade, 2018

Corrosion susceptibility of aeronautical Al-Li alloys

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Abstract. The development of third generation Al-Li alloys traced to the late 1980s in order to design a weldable aluminium based alloy having low density for use in aerospace launch vehicles and cryogenic tankage. The driving force for development and use of Al-Li alloys has been the improvements in specific strength (strength/density) and stiffness (elastic modulus/density) offered by the addition of lithium. Additionally, Al-Li products offer great advantages in aerostructural performance through density reduction, stiffness increase, increases in fracture toughness and fatigue crack growth resistance, as well as enhanced corrosion resistance.

The improvements in strength properties of Al-Li alloys are attributed to their composition and complex precipitation system that includes different kind of precipitates. Additionally, dispersoid particles are formed by the addition of other alloying elements that control the recrystallization of the metal. This complex precipitation system may influence the corrosion susceptibility of third generation Al-Li alloys because of the different electrochemical potential of the formed phases within the aluminum matrix or of the adjacent precipitates. The predominating corrosion mechanisms on Al-Li alloys will be discussed at the microscale as well as at the macroscale. At the micro scale, the effect of the precipitates and the chemical composition on localized corrosion will be assessed. At the macro scale, the pitting and micro-cracking formation on the newly developed Al-Cu-Li alloys will be discussed as well as their effect on the structural integrity coupons and aircraft components.

, Lighting Pole Health Monitoring for Predictive Maintenance

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Abstract The structural health of lighting poles is of great interest. Extensive corrosive damage of lighting poles may lead to unexpected falls of poles, which may cause dangerous injuries and accidents. The Roch "Infrastrukturprojekt Straßenbeleuchtung 2000" (Infrastructure Project: Street Lighting 2000) study on the structural stability of pole systems, which is representative on a Germany-wide scale, found that 3.3% of all poles pose a hazard. The standard prevention is regular replacement of lighting poles (e.g. Prague standard in Czech Republic is replacement of each pole every 15 years). But it has been shown that some poles are deteriorated well before this period while the other poles are in perfect state after 50 years of operation.

So the smart pole replacement based on predictive maintenance principles is more appropriate and enables to achieve both higher safety and significantly decrease maintenance costs. However, there is huge number of poles to be treated (about 1 mil. poles in Czech Republic only).

There are already many methods to determine actual state of the lighting pole, e.g. based on eddy currents, ultrasound, roentgen, static loading, frequency response functions etc. Commercially available Roch Test method is based on pole compliance measurement by sophisticated device which regularly travels around pole set, loads the pole by hydraulic actuator and measures pole deflection. These methods are time consuming, must be performed by skilled worker, require installation of special equipment, access to the pole and often provide local information only (related to the position of measurement).

The experimental modal analyses of larger set of lighting poles with same design parameters in different state of health was carried out. The differences in higher eigen frequencies could clearly determined. So if the experimental modal analyses or at least one frequency response function could be measured regularly, the change of selected eigen frequency will indicated deterioration of pole state of health. Unfortunately, realization of experimental modal analyses measurement cannot be done by unskilled worker even for simple cases. It is also even more time demanding then pole loading by static force.

The pole health detection method based on eigen frequency shift determination from acceleration measurement only using ambient excitation (mostly coming from the wind or traffic) was developed. The method was tested on acceleration data measured in the field laboratory installation of poles. The poles were excited by ambient wind only.

In addition, cheap smart sensor has been developed. It is equipped with sensitive MEMS accelerometer, carries out long term acceleration series measurement, performs data evaluation based on eigen frequency shift and other quantites and it is also connected into wireless network grid. The pole thus regularly reports its state to central server. Inspection and replacement can be then aimed at problematic areas only. The further potential the sensor grid is investigated.

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Research on Bio-based Thermosets at NIMTE: From High Thermomechanical Properties to Functionalization

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Abstract Driven by the pressure from energy and environment, more and more attention has been paid on the exploration of polymers derived renewable resources, i.e. Bio-based polymers. We are all very familiar with the bio-based thermoplastics, such as PLA, PHBV and PBS et al. As for the bio-based thermosets, the attention is far from enough. About 10 years ago, we have been devoting ourselves to the research on bio-based thermosets, for the purpose of developing GREEN composites. In this talk, the bio-based epoxy made from rosin acid and itaconic acid with high thermomechanical properties as well as their application demonstration will be overviewed. After that, the functionalized epoxy derived from daidzein and genistein will be introduced. Without addition of any flame-retardant elements, they demonstrate excellent fire resistance, ranked as V0 grade. It can be expected that, using the special chemical structures of biomass, the thermosets with high performance could be developed, which has great potential to partially replace the petroleum-based ones for GREEN composites manufacture.

, High Strain-Rate Behavior of Carbon-Epoxy Composites for Lightning Strike Protection

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Abstract The objective of this work is to investigate the dynamic mechanical behavior of carbon fiber reinforced epoxy composites with improved lightening striker protection (LSP) characteristics. Dynamic tension and compression tests were carried out using Split Hopkinson Bar (SHB) apparatus along with high speed photography and Digital Image correlation (DIC) technique to monitor the local strain distribution on specimens during impact tests. Experimental characterization under standard conditions was also carried out in order to examine the effects of through-thickness electrical conductivity modifier along the interlaminar regions of the samples on both quasi-static and dynamic responses of epoxy based carbon fiber composites.

This work was supported by the funding: MOST-FCT Project reference JICAM/0002/2017

, Hydrothermal Ageing Performance of Nano-clay Modified Flax Fiber Fabric Reinforced Epoxy Plates

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Abstract The high hydrophilic characteristics of natural fibers brings in a concern of the application of its reinforced polymer composites in many fields, because the moisture uptake may deteriorate the dimension stability, mechanical and thermal properties. In the present article, nano-clay was used to modify a flax fabrics, and the modified fabrics were then saturated with epoxy resin to prepare a composite plate with a vacuum assisted resin infusion process. The plate was subjected to 80%RH at various temperatures. The moisture uptake, mechanical properties and glass transition temperatures of the composite plates were studied as a function of exposure time.

The water absorption pattern of these composites was found to follow the classic Fickan law. The plate with nano-clay treated flax fabric shows a saturated moisture uptake by 30.9%. Compared to the control composite plate, the degradation in the tensile strength and modulus for the nano-clay treated flax based composite plate was much reduced with the high humidity exposure. The nano-clay is expected to reduce the diffusion of water molecules into the flax fibers, and to increase the bonding between the flax fiber and resin matrix, which contributes to the enhanced hydrothermal ageing resistance of the composite plates.

, Experimental measurement of bridge deflection using Digital Image Correlation

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Departamento de Engenharia Civil e Geologia, Universidade da Madeira

Abstract

Civil engineering bridges usually face a multitude of loads, ranging from strong winds to intense traffic. Thus, it is important to understand their behaviour if one is to properly maintain them in good operating conditions.

The present work presents an image sensing methodology for deflection measurement that was employed on the Entre-Águas bridge in Caniçal, Madeira, Portugal. For the application of two-dimensional Digital Image Correlation, it was necessary to place a target pattern in the monitoring region and a camera setup in stable ground on a plane orthogonal to the target. Two different 2D DIC software packages were then used for the calculations, one commercial and one self-developed, enabling their comparison and increasing the confidence in the experimental results.

The developed system was applied in order to analyze the effects of the passage of 30-tonne trucks in the bridge, with promising results.

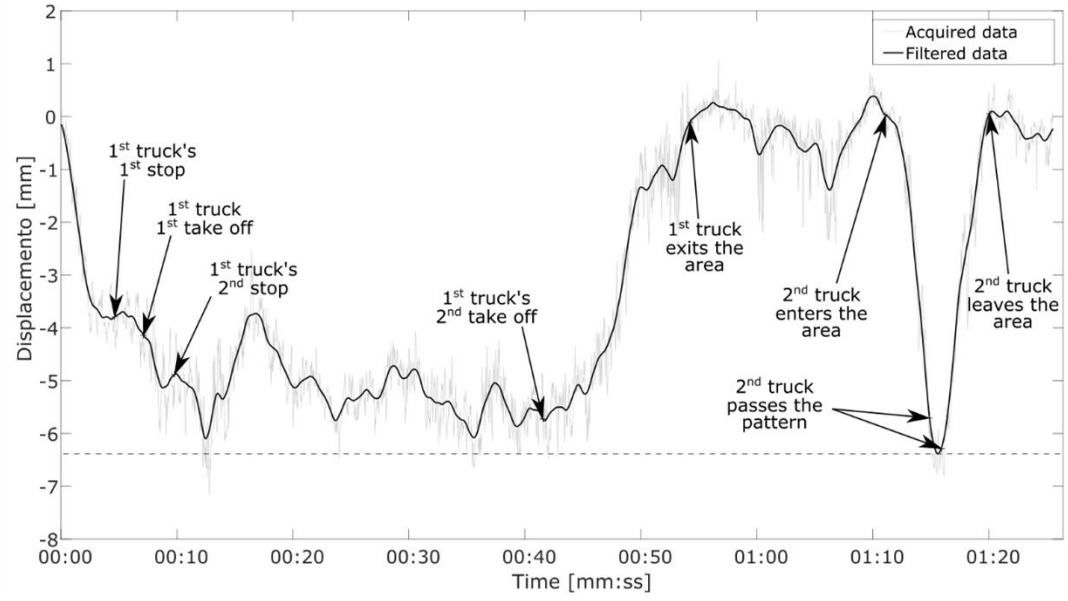

Figure 1 – *Average displacement of the speckle pattern obtained using the developed digital image correlation system*

, Displacement analysis of rotating RC helicopter blade using coupled CFD-FEA simulation and digital image correlation

Pedro J. Sousa[1,2], Francisco Barros[2], Paulo J. Tavares[2], Pedro M. G. P. Moreira[2]

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Abstract

Rotating structures are commonly used important parts in the transportation and energy generation fields, where a better understanding of these structures is advantageous for both the design and the maintenance phases. The present contribution presents a comparison of results for the rotating blades of an RC helicopter obtained using fluid-structure interaction in a computer fluid dynamics (CFD) model with measurements performed in the physical object using a digital image correlation (DIC) methodology. First, in order to obtain an accurate representation of the blades, the material properties of the blades, namely Young's Coefficient, Poisson's Ratio and Density, were obtained experimentally. These parameters were used in the simulation, where fluid-structure interaction was defined between a fluid model using Reynolds Stress Transport viscosity formulation and a finite element model. Afterwards, the obtained results were compared with actual measurements and the differences between them are analyzed. It was noticed that the major differences between these results are due to the coupling between the blades and the hub since the former are able to rotate freely in respect to the latter and small gaps, in the range of 0.05 mm, highly affect the results. Thus, the present work highlights the necessity of accurate representation of hub connections, even if the gaps are difficult to measure. Using live measurement techniques, it is possible to obtain the actual behavior of the blades, and either reflect the measured differences in computational models or detect issues with the physical specimen.

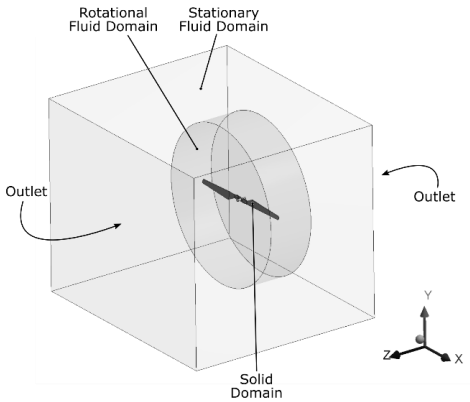

***Figure 1** – Boundary conditions and computational domains of the model*

, **Experimental study of the damage accumulation in composite materials and ceramic coatings by using of acoustic emission technique**

Ekaterina M. Zubova[1], Elena M. Strungar[2], Dmitriy S. Lobanov[2], Valery E. Vildeman[2]

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Abstract. Wide application of composite materials in reliable structures leads to the need for a detailed study of the processes of deformation, damage accumulation and fracture. Additional diagnostic methods for the experimental study of such processes in materials under the action of loads are used. Receiving and analyzing new experimental data will allow in the future to timely detect defects that indicate a decrease in the bearing capacity of the structure or may lead to the loss of its integrity.

As an additional methods for diagnosing of damage accumulation and destruction of a ceramic coating under loading the method of digital image correlation (DIC) and acoustic emission technique (AE) were used in this work. The main purpose of the work is to confirm the operability of the coating under workloads.

Acoustic emission signals were analyzed and graphs of the dependencies of the main parameters of the signals on time were plotted. In addition, fields and diagrams of the distribution of longitudinal deformations ε_{yy} along the entire length of the tested sample were constructed. The parameters of acoustic emission signals that characterize the processes of destruction of the ceramic coating were revealed. It is noted that the method of identifying the parameters of the acoustic emission signal used in this work can be implemented on various materials and coatings.

Acknowledgement. The reported study was funded by RFBR according to the research project № 18-31-00452.

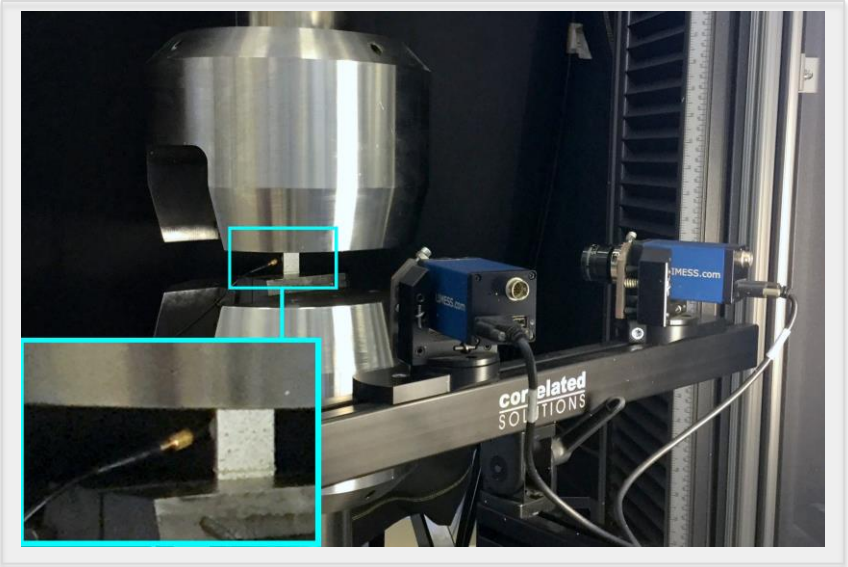

Figure 1 - *photo of tensile test*

, **Development of LED-based illumination system for high-speed digital image correlation**

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.

Abstract

The present work describes the design and development of a dedicated illumination system for application to high-speed digital image correlation. This type of application requires image acquisition to be performed with very short shutter times. This means that there is less time to integrate the oncoming light and, as such, it is necessary to have significant light flux in order to be able to acquire quality images. As such, illumination is usually the major concern in such high-speed imaging applications.

The developed system uses a strobing high-power LED light source to tackle this issue, and illuminate the specimen with a large light flux during a very short period. This reduces the amount of heat that the specimen receives from the lighting source and has the advantage of allowing the use of cameras that would otherwise be unable to use such short shutter times effectively.

In this paper, the whole design of the device is described. From the control electronics to the mechanical design, including the optical design of an appropriate reflector.

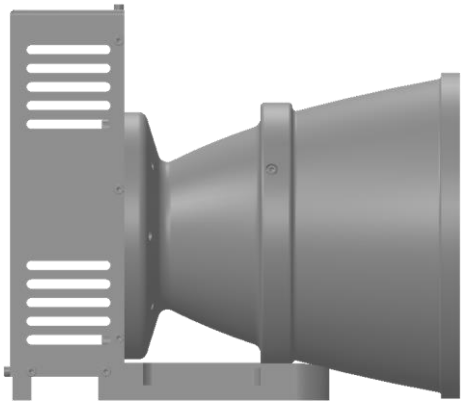

Figure 1 – *Final mechanical design of the developed system*

, Application of 3D electronic speckle pattern interferometry for analysis of thermal response in printed circuit boards

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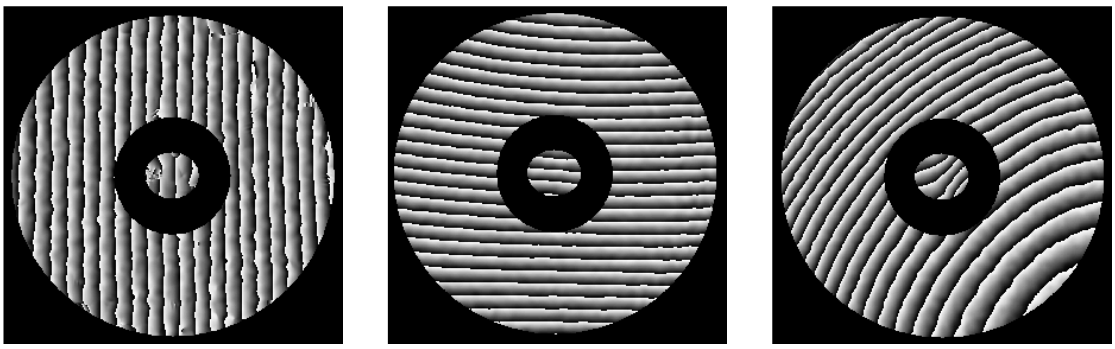
.

Abstract

The present work reports the development of a method for measurement of sub-micrometer displacements due to the thermal response of printed circuit boards.

The developed system employs Electronic Speckle Pattern Interferometry in three dimensions, obtaining three orthogonal displacements of the specimen's surface from the resulting phase maps. Afterwards, the displacements are corrected, removing the rigid rotation of the physical support and the relative rotation between the two regions of interest is calculated.

This method provides a very high-resolution displacement measurement tool, which is very important, for example, in the design phase of outdoor surveillance cameras to optimize image quality.



X axis Y axis Z axis

Figure 1 – *Filtered phase maps for the region of interest inside the specimen*

, **Classification of multiple acoustic-emission features for the safety evaluation of a road bridge under service load and environmental changes**

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Abstract Monitoring the condition of road bridges in real time as a part of sustainable management involves the use of non-destructive techniques to perform an appropriate evaluation without creating damage or interrupting traffic. Acoustic Emission (AE) is a non-destructive technique that was widely used for bridge assessment. The potential of this technique to detect damage in reinforced concrete structural elements was demonstrated in different laboratory tests. Many features can be extracted from AE signal, but only detailed analysis and appropriate correlations can lead to inclusive and useful information.

This paper presents a classification methodology of multiple AE features to obtain useful information about the structural safety of a reinforced-concrete slab under service. AE technique was used for real-time in-situ monitoring and was combined with strain gauges and thermocouples to evaluate the variation of AE features with traffic and temperature changes. The classification was based on receiver operating characteristics where an optimum threshold was calculated for each feature.

It is shown that some AE features are more sensitive to traffic and temperature variations than others are. The correlation of the classified AE features gives useful information about the changes in concrete and presents a base to an appropriate detection of damage evolution in reinforced-concrete slabs under service loads and environmental changes.

, Mechanical Properties of 18Ni-300 maraging steel manufactured by LPBF

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Abstract The purpose of this document is to investigate the influence of heat treatment on the mechanical properties of parts from MAR 300 (EN 1.2709) produced by laser powder bed fusion (LPBF). In order to compare the influence of the heat treatment on the parts properties, some parts were in the state solution annealed and others age hardened tested. Age hardening at 490 ºC for 6 hours was applied for improving the mechanical properties. The starting material has a decisive influence on the achievable quality and properties of the end product and thus forms the basis of the present investigations.

Therefore, powder characterization has been performed in order to work out ageing effects after multiple use. As a major ageing effect an increasing oxygen content could be identified which might affect process and parts quality. Different powder states (e.g. new, sieved and waste) were characterized for this purpose. Similar samples were produced with the LPBF process by an EOS M290 metal printer. For industrial acceptance, AM parts need to be produced to the best available tolerances and with well-understood mechanical properties. For this purpose, the mechanical properties of the LPBF samples have been analysed and are compared to those properties for conventional samples. In this investigation, the mechanical tests (hardness test, tensile test and notch impact resistance) have been performed in horizontal and vertical directions of manufacturing by LPBF. The hardness increased from 333~341 HV10 to 640~656 HV10 after heat treatment. Simultaneously, the ultimate tensile strength (R_m) increases from 1056~1096 MPa to 1964~2102 MPa, while the break elongation (ε_{tot}) is reduced from 11.3~16.0% to 2.0~4.5%. Aged samples show a significant decrease in toughness in the Notch Impact Test. A specifically designed ball joint test setup has shown that the frame manufactured by LPBF provides comparable results as a conventionally manufactured frame and is robust and suitable for the prototype production and test of car headlamps.

,

On instabilities of growing bi-material interfaces

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Abstract A variety of morphological patterns initially arise on surfaces of growing precipitates at small length scales. The patterns could be ridges, wrinkles or fringes. Formation of these patterns directly influences the final shape of precipitates, and are assumed to be mainly caused by the change of volume of the new phase. To better understand the cause of different patterns an analytical study of the stability of the precipitate-matrix interface is performed. First a wavy interface perturbation is used to examine the spontaneous variations that occur at the precipitate-matrix interface. The analysis utilizes Cerruti's solution to compute the perturbed stress field surrounding the interface. It is shown that a virtually flat surface subjected to tension is in general unstable. The amplitude of sinusoidal perturbations decays for short wave lengths and grow for longer wave lengths. Both a critical wave length for which the perturbation amplitude is unaffected and a specific ditto which obtain maximum perturbation growth rate are derived.

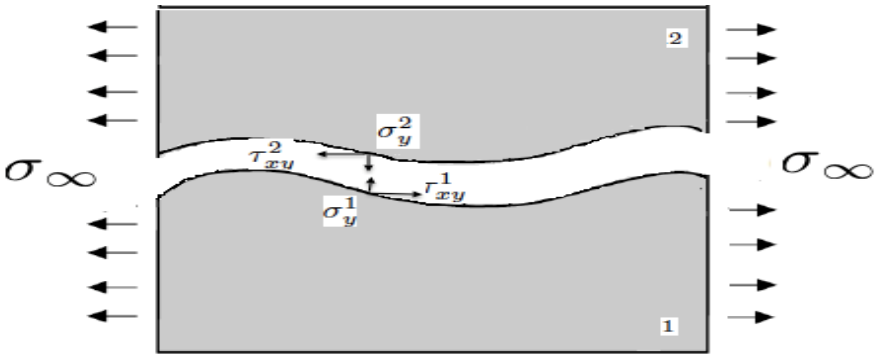

Figure 1 – *Stress field at wavy interfaces*

, Mechanical Characterization of Sandwich Composites with Embedded Sensors

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Abstract Sandwich composite materials have been used in aerospace structures due to their high stiffness and lightweight. The fact that these materials are anisotropic and have complex failure modes has led to the evolution of a structural health monitoring (SHM) systems, which uses sensing systems to detect and characterize the structural integrity of a component. The configuration of a composite makes it difficult to predict its structural behaviour using only surface sensors, since internal material damage can occur, and cannot be detected by Non-Destructive Tests (NDT) or visual inspection. In order to solve this problem, the embedded sensors appear as an alternative to measure the deformation in internal regions of the composite. The objectives of this work are the development of a methodology for introducing strain gauges and fibre Bragg grating sensors on the surface and embedded them in a sandwich composite material, carry out stiffness tests (flexural and tensile tests), and creep tests. This material consists of a cork agglomerate core with glass fibre skins and epoxy resin. The core was selected since it is a material that presents a high mechanical resistance to shear loads, good thermal and acoustic insulation capacity, which dissipates the deformation energy. The obtained results are validated by comparison with the results provided by the Digital Image Correlation program. Finally, it is intended to assess whether measurements are reliable and how embedded sensors change the mechanical behaviour of the material.

, **Numerical Modelling of Flexural Behaviour of Cork-Core Sandwich Composites**

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Abstract The use of cork core sandwich composites has increased due to its high shear strength when compared to other core materials, improved thermal and acoustic insulation properties and a low environmental impact. Considering the nonlinear elastic behaviour of cork, it is important to predict accurately the final structural behaviour when this type of material is used to manufacture composite components. In this work, a standard composite sandwich consisting of a cork agglomerate core reinforced with an fibre glass epoxy skin was modelled and studied using finite element analysis (FEM). The granular nature of this core material and the production method of the composite panels difficult the numerical prediction. During production, the laminate is hot-pressed which compresses the cork, increasing its initial stiffness. The cork agglomerate also absorbs resin, creating a region where cork is reinforced by resin impregnated between the initial cork panel and both skins. The finite element model of this composite was created in which a new layer between the initial cork panel and both skins is modelled as a different material, that will become a function of the open porosity of the cork agglomerate. All results obtained are compared with data from four-point bending tests carried out in previous works, and allow to conclude that this new FEM approach can be used to accurately predict flexural behaviour of different cork core sandwich composite configurations.

,Oxidative Treatment of Multi-Walled Carbon Nanotubes and its Effect on the Mechanical and Electrical Properties of Green Epoxy based Nano-Composites

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Abstract Oxidative treatment of Multi-Walled Carbon Nanotubes (MWCNT's) was done by chemical functionalization using mixture of sulfuric (H2SO4) acid and nitric acid (HNO3). Functionalization was governed by the parameters such as mixture acids concentration, temperature, time of heating and amount of MWCNTs. Functionalized MWCNT's were diluted in dimethylformamide (DMF) and the amount of MWCNT's yield obtained after functionalization, as well as, the percentage of soluble MWCNT's in DMF were analysed. By increasing the time of functionalization, it was observed that overall yield decreases but the percentage of functionalized product inside the yield quantity remains the same. Material characterization was also addressed.

Chemical functionalization of MWCNT's is generally significant for the manufacturing of polymer-based nanocomposites, since the oxidative treatment enhances their dispersion and interfacial bonding within the epoxy matrix. A bio-based epoxy resin was selected for the manufacturing of nanocomposite samples with various concentrations of not functionalized and functionalized MWCNTs. Mechanical and electrical characterization was finally carried out to increase the knowledge on the interaction of MWCNT's with the selected green epoxy matrix system and their influence on the original properties of the resin.

Study of The Regularities of Postcritical Behavior and Failure of Specimens in the Tests of Composite Materials

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Abstract The development of the models of mechanics of deformable solid, which describe the postcritical stage and the corresponding fracture conditions, is important for improving the methods of refined strength analysis of critical structures, predicting their behavior and estimating survivability, including the describing the processes at the crack tip. The wide applicability of polymer composite materials in the manufacturing of critical structural elements that operate under conditions of complex thermomechanical effects, determines the actuality of studying the occurrence of limiting states and the destruction of composites under various loading conditions.

New experimental data on the regularities of deformation and fracture of layered glass and carbon plastic composites with various reinforcement schemes were obtained. Particular attention is paid to the manifestation of the postcritical behavior of composites, which is characterized by a decrease in the load that the sample is able to perceive, with a monotonous increase in displacements. In this case, the postcritical deformation stage is associated with the development of damage accumulated during the loading process, interaction of defects and subsequent partial destruction of the structural elements of the composite material. The tests were carried out on the samples of various shapes under tension, compression and three-point bending in a wide range of temperatures. The influence of temperature on the regularities of deformation and fracture of polymer composites and the realization degree of the postcritical deformation stage has been estimated. Methodical issues of experimental study of the effect of the rigidity of the loading system on the postcritical deformation and destruction of polymer composites under compression, three-point bending and interlayer shear (short beam method) are considered when using various combinations of disc springs in the loading circuit. Experimental data on the effect of the rigidity of the loading system on the realization of the equilibrium stage of postcritical deformation during the destruction of composite materials during the interlayer shear are obtained. The structure of the destroyed prototypes was analyzed.

The work was carried out with support of the Russian Science Foundation (Project 16-19-00069) in the Perm National Research Polytechnic University.

,Crack closure measurement in Al2024 compact tension specimen subjected to random loading

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Abstract In this work a new procedure for the experimental determination of crack opening load based on ASTM offset compliance method is presented. The method is applied to a broadband random loading process on a fatigue crack grown on a compact tension Al2024 specimen. The very good results observed suggest that the new procedure could be used for general loading processes and not only for constant amplitude or slowly changing loading, as it is recommended in the standards. Additionally, the good agreement between the opening load experimentally obtained by the new procedure and the calculated values by the Strip Yield Model increase the reliability of this model. It is expected to extend the proposed methodology to other materials and loading spectra.

, Estimation of the plastic zone in fatigue through the thickness based on synchrotron diffraction data

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Abstract In this work we present a novel methodology to analyse the plasticity inside engineering materials. The plastic zone developed ahead of a fatigue crack in a bainitic steel compact tension specimen is studied. The bulk of the steel is probed with synchrotron X-ray diffraction technique that can be used to measure the elastic strain field deep inside the material. The procedure involves combining the experimental synchrotron data with numerical data to obtain the equivalent strain map. This map is then converted into a stress field where the boundary of the plastic zone can be directly extracted. A summary of the procedure is shown in Figure 1. The procedure is tested on different lengths of a fatigue crack and the results are compared to plane stress and plane strain models. The promising results will enable key progress on understanding the mechanisms that generate the damage at the tip of fatigue cracks in engineering components.

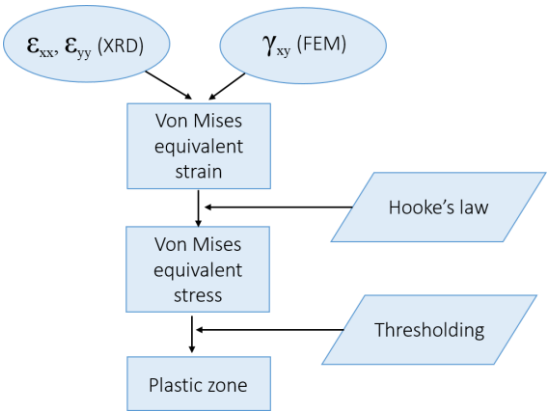

Figure 1 - *Flow chart summarising the different steps for obtaining the plastic zone from synchrotron X-ray diffraction data.*

, SHM TB30, Numerical Study of an Aircraft Structural Condition

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Abstract The purpose of this paper is the estimation of the Fatigue Lifetime of the Portuguese Air Force's Epsilon TB-30 aircraft, by strain analysis on critical components of the aircraft.

The experimental studies and knowledge of aircraft loads was used to reverse engineer a suitable Finite Element Model of the structure, from which the stress fields in previously identified structural hotspots were retrieved.

Cumulative damage on the structure is calculated for reference loading spectra using the Palgrem-Miner rule and suitable fatigue criteria.

The Stress Intensity Factors at the critical component's notched geometry were estimated using two different approaches: the Finite Element and Extended Finite Element Methods from ABAQUS. Crack propagation was then modelled using several laws (Paris, Walker, NASGRO, Forman). A comparison between the two numerical methods and the results of the several propagation laws are presented. Parameters for the various equations for Al 2024-T3 are obtained through the fitting of prior experimental data.

Lastly, it was suggested new scheduling of maintenance activities to adjust the manufacturer's spectrum results to the loading conditions of the aircraft.

, Prediction of fatigue life of a Portuguese Air Force aircraft

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Abstract The objective of this paper is to collect and analyse the fatigue data of the PrtAF Epsilon TB-30 fleet related to vertical loads (G-factors) and stress in several critical points along the wing and fuselage. This works compiles the analysis of more than 800 Flight Hours and the definition of transference function from G's to stress on those stress points. So, based on the data collected the severity of the Portuguese Air Force operation will be compared to the severity stablished by the manufactured during real scale fatigue test. To do so, it was chosen one wing critical location and a representative test samples was designed to represent the typical stress field running on the wing. Two sets of 4 samples were produced, the first set was used to simulate the PrtAF spectrum in the critical location and the other 4 were used to simulate the manufacturer spectrum. The experimental results were compared to the AFGROW simulations. Base on the results of the experimental study the initial inspection intervals were adjusted to guarantee that are adequate and suitable to the PrtAF severity of operation.

, Failure Analysis of the Upright Component of FST08e Suspension System

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Abstract

This paper presents a failure analysis of the upright component of the suspension system. This component belongs to the suspension of a prototype vehicle of the Lisbon University Formula Student team.

The component was manufactured by a CNC machine in two steps with an upside down exchange position. This introduced some concentricity misalignments on the cylindrical surfaces which support the axle bearings. As a result, a large number of fatigue cycles arise during the rotation of the wheel, and a fatigue failure appears after some hours of running the vehicle on the tracks and practice areas.

This work involved the detailed analysis fracture's surface using optical and scanning electron microscopies. Those observations are intended to obtain the photographic images of the failure surface for failure mode determination.

A finite element model was performed to verify these manufactured misalignments causes such stress levels promoting the fatigue fracture of the component. Also a modified geometry was created and analysed to improved strength of the component.

, Numerical and Experimental Analysis of the Suspension Connection Area of a Formula Student Monocoque Chassis

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Abstract

Sandwich structures are widely used in motorsport and transportation industry due to their high bending stiffness allied to lightweight characteristics. Despite these properties, they are very weak to withstand localized loads, requiring a reinforcement to disseminate the effort into a larger area. Normally, those reinforcements are inserts but, in this work, a new approach is studied where the honeycomb core is locally removed and the inner skin joins the outer one, creating a rigid attachment point called chamfer.

The monocoque chassis is the central piece of a racing car, so all other parts are connected to it, transmitting efforts. This work focus on the suspension attachment area of FST Lisboa's formula student monocoque chassis, analysing these two types of reinforcements in terms of inserts diameter and chamfer geometry. A finite element model was built in order to set the comparison between the different geometries, first separately and then when included in a suspension quarter. Subsequently, the geometries with best results were chosen and a laminate layup optimization was made. Lastly, for validation of the analytic model, four specimens of each one of the two approaches were built and a pull-out test was performed on them, with a custom developed apparatus.

Failure modes similar to those theoretically previewed were achieved and a finest correlation between the experimental and analytical results were found for inserts than for chamfers, probably due to inevitable manufacturing errors. Lastly, the results were applied in the construction of the team's new prototype monocoque.

, Numerical analysis of the influence of the last cycle scheme on plasticity induced crack closure

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[2]Centre for Mechanical Engineering, Materials and Processes, Department of Mechanical Engineering, University of Coimbra, Portugal

Abstract Plasticity Induced Crack Closure (PICC) is considered the main mechanism related to the premature contact of the crack flanks when a crack grows under cyclic loadings. This phenomenon has been studied numerically since the early 70's, when some researchers approached to metal fatigue problems by means of the finite element analysis. Most of these analyses have been performed considering bi-dimensional models. Lately, the use of three-dimensional models has been extended.

A great number of numerical parameters have to be taken into account when this kind of problems are analysed. The mesh size, the material model, the number of loading cycles, how the contact between crack flanks is modelled, when the nodes are released and other parameters have a great influence on the results. The methodology considered in the three-dimensional models is usually inherited from previous bi-dimensional studies of the influence of these parameters. The current computational capabilities allow a comprehensive study of the influence of these numerical parameters in three-dimensional models.

When running a finite element analysis, it is not possible to consider all the loading cycles involved in an experimental analysis. The computational cost is not acceptable. The crack growth usually is simulated releasing nodes. The numerical rates are unrealistic when comparing with real ones. Therefore, in this work, the crack growth scheme is analysed. In particular, the influence of the number of loading cycles after releasing the last set of nodes on the PICC results is studied.

For this purpose, a CT aluminium specimen has been modelled three-dimensionally. Several calculations have been made in order to evaluate the influence of the number of loading cycles after realising the last set of nodes. The results are analysed in terms of crack opening and closure values. Eight different cases have been analysed for a 3mm specimen thickness. The load applied is which corresponds to a stress intensity factor K=25MPa·m$^{1/2}$. The plastic wake length previously developed is 0.4 times the plastic size. Two different stress ratios are considered R=0.1 and 0.3. For each one, four different number of load cycles between node releases are considered ranging from 1 to 8 cycles.

, Identification of high strain rate behaviour of wood based on an inertial impact test

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Abstract Wood is a hierarchical composite material formed by trees. It has a complex and heterogeneous morphology generated by the biomechanics of the tree. In recent decades, wood and wood-based products have been enhanced by sustainable development policies. Their engineering applications spread over a wide spectrum of loading scenarios including viscoelastic, quasi-static, intermediate and high strain rate regimes.

In this work, a new image-based inertial impact test was applied for the identification of the high strain rate behaviour of *Pinus pinaster* Ait. wood. The approach coupled full-field deformation measurements provided by the grid method with the virtual fields method for extracting dynamic parameters of the material in the form of both the stiffness and strength. The test consists of apply a short compressive pulse to one face of a rectangular specimen. The pulse travels at a given acceleration field through the specimen until reaching its free edge. The pulse is then reflected in the form of a tensile loading eventually causing the specimen failure. From the displacement fields both strain and acceleration fields are then reconstructed. They are needed as input in the equilibrium equation of the Principle of the Virtual Work. The inertial impact tests were carried out using a custom built gas gun. A waveguide and projectile had a cylindrical configuration made of aluminium. Wooden samples oriented on the transversal plane were tested with nominal dimensions of 50×30×5 mm^3. The specimens were bonded to the cylindrical wave guide using cyanoacrylate glue. Images were recorded using a Shimadzu HPV-X ultra-high speed camera coupled with a Sigma 105 mm macro lens (Pixel array size 400×250 $pixels^2$; Total frames 128; Inter frame time 0.5 μs; Grid pitch of 0.7 mm; Grid sampling of 5 pixels/period; Raw displacement resolution estimation of 0.3 μm; Strain resolution of the order of 80 μm/m; Acceleration resolution of about 6×10^5 m/s^2. From the data reduction scheme based on the VFM both elastic parameters and strength properties of *Pinus pinaster* Ait. wood were determined and discussed.

, High strain rate compressive behaviour of wood on the transverse plane

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Abstract Wood is a biological composite material. It has a complex and heterogeneous structure generated by the biomechanics of the tree. Wood and wood-based products are at the core of sustainable engineering materials. Their current applications may cover a spectrum of loading scenarios including viscoelastic, quasi-static, intermediate and high strain rate regimes.

In this work, the high strain rate behaviour of *Pinus pinaster* Ait. wood has addressed using the split-Hopkinson pressure bar test. For comparison purposes quasi-static compression tests were also considered. Tests were carried out using both radial and tangential specimens. The nominal dimensions of the samples were 10×20×5 mm^3 and 10×20×10 mm^3, respectively, for the quasi-static and high strain rate tests. The digital image correlation technique was used in order to reconstruct the strain field at the gauge section of the specimens by integrating measurements over a few growth annual rings (correlation criterion: zero-normalized sum of squared difference; shape function: affine; image interpolation: bicubic spline interpolation; image prefiltering: gaussian kernel size of 5 pixels; strain windows: 9 subsets; strain tensor: Green-Lagrange; strain interpolation: bilinear quadrilateral). The DIC MatchID software was employed. A CCD Manta G-505 (2452×2056 $pixels^2$, 1 fps) and Photron FASTCAM SA-Z (320×192 $pixels^2$, 10^5 fps) cameras were selected for quasi-static and high strain rate tests, respectively.

From the data reduction schemes of both tests, the constitutive laws on both radial and tangential specimens were measured. From the constitutive behaviour, mechanical properties including Young modulus, Poisson's ration and compressive strength were evaluated from both strain rate regimes. It was founded that the measured mechanical properties increased by increasing the strain rate. Young modulus were enhanced by an average factor of 6% and 22% for radial and tangential directions, respectively, whilst the compressive strength were increased by 105% and 122%.

Experimental study of the influence of the strain-stress state on the jerky flow in metals and alloys

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Abstract. High reliability of created structures and prevention of industrial accidents are vastly determined by the availability of information about physical, mechanical and strength characteristics of used materials, considering the influence of real external actions, which cause the complex stressed state of material. Failure processes in metals and alloys are associated with changing in their structure and mechanical properties during loading. Effects of serrated yielding lead to a significant decrease of strength and plasticity, also reduce quality of material's surface. Bending and the spontaneous macroscopic localization of plastic flow lead to a non-uniform thickness, and, as a consequence, to macroscopic fracture.

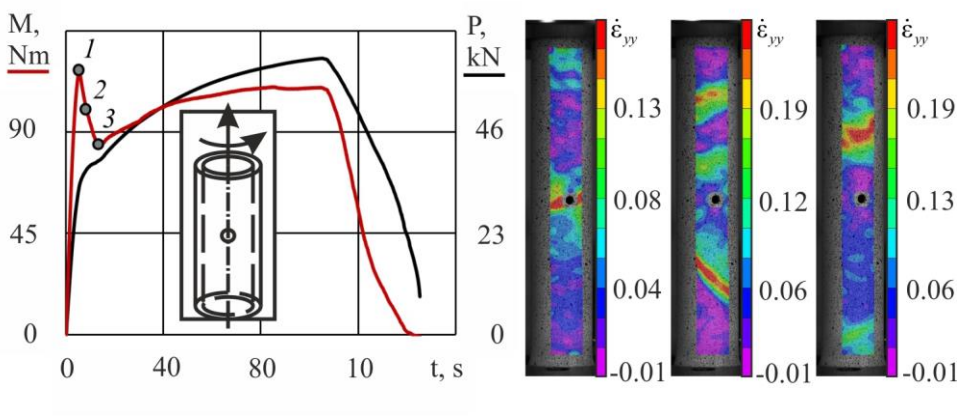

***Figure 1** – Inhomogeneous fields of local strain rate during tension-torsion loading of carbon steel tube with concentrator*

This work is concerned with improvement of experimental methods for studying the influence of the stress-strain state on the spatial time inhomogeneity die to the jerky flow on the example of Al-Mg alloys and carbon steels. The implementation of a complex stress state is based on the use of specimens with special complicated geometry and specimens with stress concentrators. Mechanical tests were carried out on uniaxial tension of plates with a rigid rim, in the working part of which biaxial tension and combined tension-compression loading is realized. Tests on proportional tension with torsion of thin-walled tubular samples with stress concentrators were provided as well (fig. 1). Evolution of inhomogeneous strain and temperature fields were analyzed by using digital image correlation technique and infrared thermography. Experimental data on the kinetics of initiation and development of the deformation bands due to the Chernov-Lüders behavior and Portevin-Le Chatelier effect in various types of stress-strain state of the material were obtained. The work was carried out in the Center of Experimental Mechanics of Perm National Research Polytechnic University and funded by the Russian Science Foundation according to the research project № 18-79-00242.

, **Compressive strength of natural hydraulic lime mortars using soft computing techniques**

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Abstract In recent years, natural hydraulic lime (NHL) mortars have gained increased attention from researchers, not only as restoration materials for monuments and historical buildings, but also as an eco-friendly material which can be used as binder to formulate mortars for contemporary structures. In the present study, an extended database related to natural hydraulic lime mortars is compiled, related to all three NHL grades (NHL5, NHL3.5, NHL2) and soft computing techniques are utilized in order to reveal the influence of the mortar's mix design on mechanical strength, as well as to predict the compressive strength of NHL mortar mixes. Namely, artificial neural networks (ANNs) and genetic programming (GP) models are used in order to predict the compressive strength of NHL mortars. Thus, the influence of binder to aggregate, binder to water and maximum aggregate size on the compressive strength of a mortar at different mortar ages is revealed, for the three grades of natural hydraulic lime, further highlighting aspects of this "new" material, which has been used as a binder since antiquity.

, Soft computing-based techniques for concrete beams shear strength

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Abstract Despite the abundance of research works, both experimental and theoretical, conducted since the middle of the previous century up to today, the determination of the shear stress value is still remains an open issue of great interest in structural engineering. The need for further research is indicated by the fact that the majority of available proposals, whether proposed by regulatory agencies or various individuals researchers, lead to the estimation of different shear stress values; moreover, the comparison of estimated values with experimental values demonstrates that the available proposals lead to an overestimation or to an underestimation of the "true" shear stress. In this research study, the artificial neural networks approach is used to estimate the ultimate shear capacity of reinforced concrete beams with transverse reinforcement. More specifically, surrogate approaches, such as artificial neural network models, have been examined for predicting the shear capacity of concrete beams, based on experimental test results available in the pertinent literature. The comparison of the consequent results with the corresponding experimental ones as well as with available formulas from previous research studies or code provisions makes obvious the ability of artificial neural networks to evaluate the shear capacity of reinforced concrete beams in a trustworthy and effective manner.

, Offshore wind bolted flange connections: Effects of tightening sequence on preload

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Abstract Wind power is currently the fastest growing energy source in the world, with an annual growth rate of around 20 percent. Most new wind farms are being installed offshore where large spaces and higher average wind speeds are available, allowing larger and more efficient turbines to be installed.

Offshore turbines in shallow water are predominantly installed using a monopile foundation, onto which a transition piece and wind turbine are attached. The monopile to transition piece (MP-TP) connection is generally made using a grouted connection, however there have been reported cases of grout failure causing turbine slippage, among other issues. One solution is to use bolted ring flange connections which provide a firm fixing between the MP-TP connection using a large number of M72 bolts.

Offshore wind operators have begun to experience preload relaxation and even full loosening of these bolts due to a number of influencing factors. It is in the interest of the offshore wind operators to reduce the number of visits to these turbines due to large operation and maintenance costs, which directly influence the levelised cost of electricity.

The present study focuses on the effect on preload of bolt tightening on based on the tensioning method. A detailed finite element model of a seven-bolt representative segment of a monopile flange has been developed with material properties obtained from the available literature. Three analysis are made to examine the effect on preload after tightening, including the initial preload level applied to the bolts, the tightening sequence and finally the effect of and additional tightening pass.

Three initial tightening loads based on 70-90% of the bolts yield strength are modelled, showing a maximum preload reduction across the bolts of around 5% experienced in all three cases. Two conclusions of these models are that higher initial preload levels lead to a larger total preload reduction and that lower initial preload levels are susceptible to a reduction below the minimum required limit set by the standards.

The tightening sequence has no effect on the final preload value of the first bolt tightened in any sequence, which experiences the largest reduction in preload. Tightening of the bolts using sequences results in preload scatter across the bolts. A second pass was modelled using the same tightening sequence as the first pass which results in all bolts meeting the targeted level of preload.

Influence of Structural Failure on Crash or Post-Crash movement for Power Two Wheelers Vehicles

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Abstract

Claiming more than 1.35 million lives each year and causing up to 50 million injuries, road traffic accidents represent the eight leading cause of death globally. Road traffic accidents is currently the leading cause of death for children and young adults aged 5-29 years old. Road traffic crashes cost most countries 3% of their gross domestic product representing a huge social and economic issue. Two wheelers (TW) vehicles that includes motorcycles, mopeds and bicycles represents 31% of the fatalities worldwide in traffic accidents. This way, accident reconstruction takes a very important role in order to determine the accident dynamics and to investigation of the causes and the responsibility of an accident. After the impact of a TW with another vehicle or with an element of the road, it is going to suffer some damages and deformations. Structural failure can occur especially in the front parts of the TW (front wheel and front suspensions). What is the impact on the results of computational simulations of a PTW accident when that deformations are not considered? Using the software PC-Crash, the influence of the change of geometry in a PTW due to its damages is going to be analyzed. To consider the deformations of a PTW in the computational simulations, different multibody models are going to be considered and modified (Figure 1). The movement of the vehicles is going to be analyzed in the impact phase and especially in the post-impact phase. Also fracture can occur in front suspension and that leads to the crash. A case study of a motorcycle that was suspected to have fracture in the front suspension is presented where from the analysis of the fracture combined with the results of the accident reconstruction has proved that the fracture occurred during the crash. Different examples with structural failure and separation of structural elements as a consequence of the crash are examined to verify how this influences the post-crash motion. In general the structural separation don´t affects significantly the post-crash motion.

Effects of residual stresses and localised strain-hardening on the fracture of ductile materials

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Abstract The strain history of a ductile material can affect its apparent initiation fracture toughness as well as its resistance to subsequent crack growth. Using neutron diffraction or synchrotron X-ray diffraction in conjunction with digital image correlation, it is possible to map both the total strain around the tip of a propagating crack, and the elastic strain component. Separating the elastic and irreversible strain components allows us to experimentally investigate the effects that residual stresses and prior strainhardening have on crack propagation. This article presents the results of two experiments using these techniques. In the first experiment, it was shown that residual stresses in a 7xxx-series aluminium alloy affect not only the initiation of fracture but also fracture propagation. During crack propagation, residual stress relaxation occurs due to extension of the crack and plastic deformation in the region ahead of the crack tip. This affects the material's apparent crack growth resistance in a non-linear manner and hence changes its fracture stability. In a second experiment, it was shown that the plastic zone ahead of a crack in a ductile material (in this case a ductile ferritic steel) can be modified by localised strain-hardening prior to fracture. Localised strain-hardening using an indentation tool was observed to cause small increases in the specimens' peak load capacity and its energy absorption prior to the onset of unstable tearing. Using synchrotron diffraction, it was shown that is because hardening a region ahead of the crack tip causes stress redistribution to this region and away from the crack tip itself during fracture loading. These findings can inform how ductile and semi-ductile fracture is treated in structural integrity assessment procedures, particularly in the presence of residual stress. They also suggest that new localised peening treatments to improve the fracture resistance of structures in certain areas may be possible.

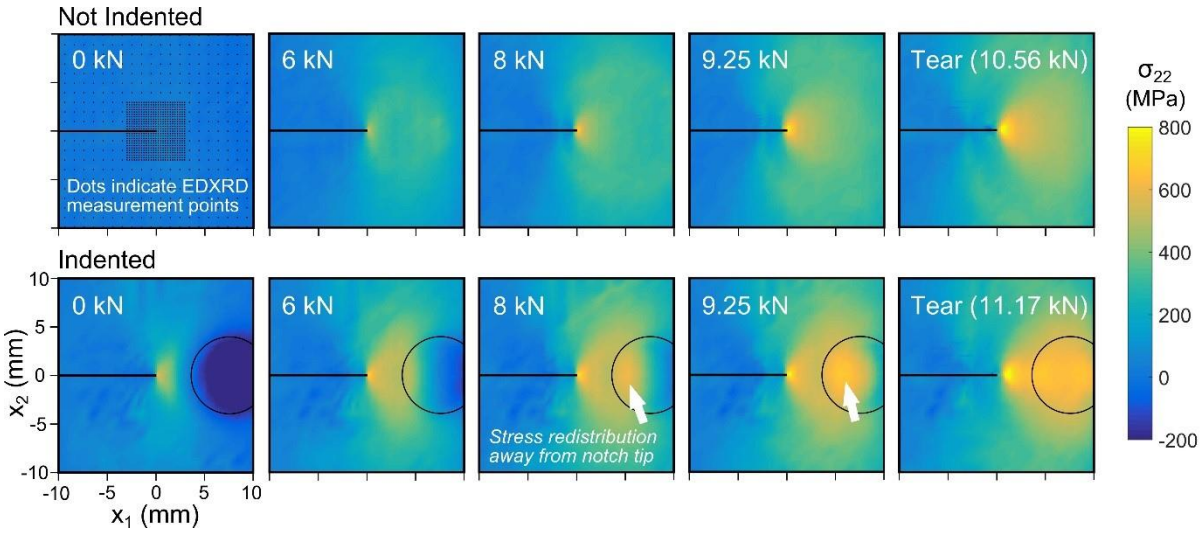

Figure 1: *Stress distribution around the tip of a notch in two thin fracture specimen of ferritic pressure vessel steel, measured using synchrotron X-ray diffraction. Upper row: plain specimen, lower row: specimen with round indentation ahead of the notch tip.*

, **Investigation of a test method for the determination of strain rate-dependent material properties of high-performance fibers**

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Abstract For reinforcement in fiber reinforced plastic and concrete applications, the knowledge of the high velocity impact and crash behavior of the typically used high-performance fibers, such as carbon fibers (CF), becomes an important aspect for the designing and dimensioning of new composite components. More important than the impact velocity is the resulting strain rate in the fiber, which defines the failure behavior. In the current literature, there is still an open gap for fiber material testing for strain rates between 100 and 1000 1/s, which is difficult to close with the existing measurement setups. This gap between servo-hydraulic tensile testing machines and SPLIT-HOPKINSON-tension-bar can be closed with a rotary drive principle (Figure 1). The challenge arises in coupling the force, in a reliable clamping of the specimens and in high-speed acquisition of the stress-strain curve. In the implementation process, speeds up to 40 m/s were currently achieved. The specimen and the moving elements were prepared with stochastic patterns (Figure 2) and evaluated by means of DIC. The force signal is recorded and correlated from both of two independent sensors, piezoelectric load cell and coupled one-bar as described in the standard ISO 26203-1. For the analysis of the measuring system, an analytical model was additionally set up and evaluated using SPICE® simulation tool. After analysis of high-speed images by DIC it can be concluded that there is a partially elastic impact and acceleration does not reach its maxima before the specimen's rupture. Thus, for a precise evaluation, the stress equilibrium has to be taken into account and the impact process has to be further optimized.

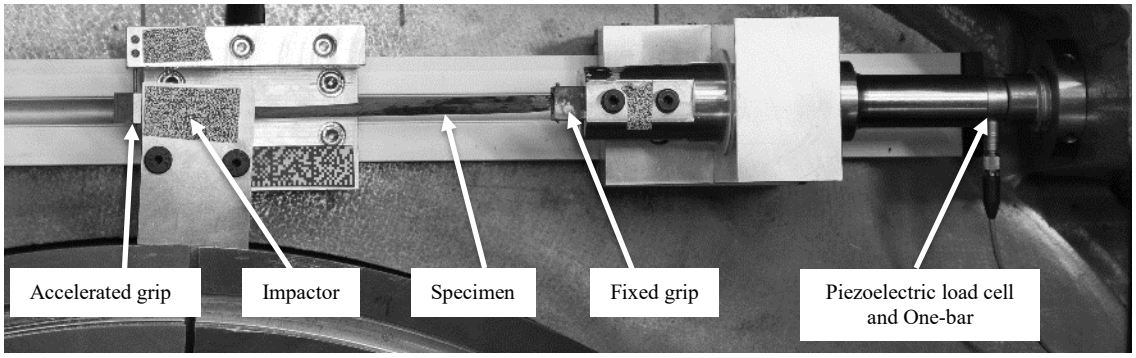

***Figure 1** – Probe set-up of high-strain-rate rotary drive-based fiber testing machine with one-bar* | © ITM, 2019

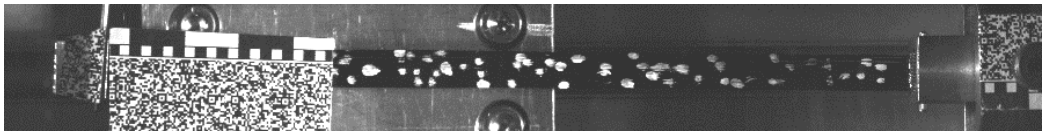

***Figure 2** – High-Speed image of CF specimen while high-velocity straining*

, Evaluation in Fatigue Life of 300 M Steel After Laser Carburizing an Plasma Nitriding

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Abstract In this work is used a 300M steel after received a specific heat treatment. This high-strength steel is used in aeronautic and aerospace industry. It was developed from SAE 4340 steel with a increment in a chemical composition, mainly vanadium and silicon. The goal of this improvement was get better toughness in applications requiring improved in mechanical properties. Initially the 300 M steel was submitted a heat treatment to obtained a bainítica structure, it is heated at 850 ºC for 30 minutes and after that is cooled at 300 °C for 60 minutes. Afterward was used two types of surface treatments: (a) using low-power laser CO_2 (125 W) for introducing carbon into the surface of 300M steel and (b) plasma nitriding at a temperature of 500° C in atmosphere having N_2 and H_2 gas mixture. After surface treatment, the metallographic preparation was carried out and made the observation with optical and electronic microscopy. The analysis of the coating showed an increased in the hardness of layer formed in the surface, mainly, in the nitriding layers. The thickness of the compound layer formed on the surface was around 20 µm and the heat affected zone was around 45 µm for de laser carburizing layer and around 60 µm for the plasma nitriding layer. The mechanical properties were analyzed using tensile and fatigue tests (Fig.1). The results showed that the mechanical properties in tensile tests were strongly affected by the bainitic microstructure. The steel that received the nitriding surface by plasma treatment showed better fatigue behavior. The results are very promising because the layer formed in steel surface, in addition to improving the fatigue life, still improves protection against corrosion and wear.

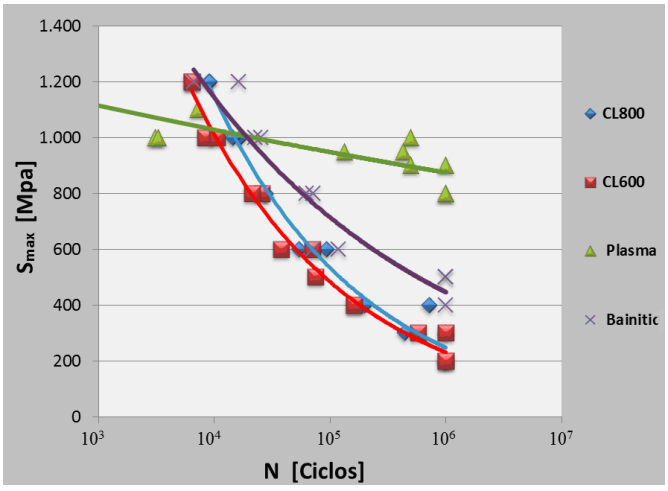

***Figure 1** – Fatigue life curves of 300 M steel with different surface treatments.*

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Fatigue Performance of Friction Stir Weld-Bonded Al-Mg joints

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Abstract The need for weight reduction and leaner manufacturing and assembly processes in aircraft construction has led to the pursuit of alternative joining processes to conventional riveting. One such technology that has been considered for this application is friction stir welding (FSW). Since it is a solid-state joining method, it results in high performing joints in a wide range of materials while avoiding overlap lengths and added weight from fasteners, crack stoppers, doublers, etc. However, the adoption of this technology to the assembly of large fuselage shell components is challenging, due to geometric tolerance management requirements. A hybrid friction stir weld-bonding method combining overlap friction stir welding and adhesive bonding has been proposed as an alternative. Fatigue performance of such joints were assessed and benchmarked against overlap FSW and adhesive bonded joints.

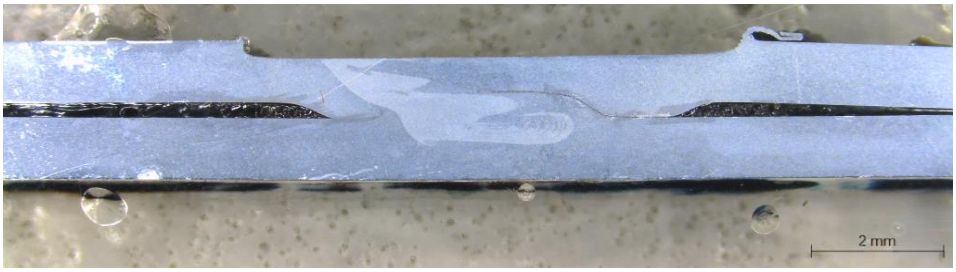

Figure 1 - Overall view of AA6082-T6 hybrid overlap joints.

, An experimental and numerical investigation of the crushing behavior of 2D woven CFRP Formula 1 crash structures

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Abstract The commercial design tools currently available to F1 teams do not cater for accurate simulations of composite material crushing. Consequently, extensive physical testing is required during the development phase, making the process prohibitively expensive unless significant limits are placed on the design space that can be explored. Through the use of better numerical predictive tools, namely Finite Element (FE) composite damage models, engineers will be able to accurately predict the behaviour of crash structures, allowing them to better optimise the final designs within a shorter timeframe and in a cost-efficient manner.

Here we present a qualitative and quantitative experimental assessment of the crushing behaviour of an F1 side-impact structure subjected to quasi-static loading.

A quasi-static crush simulation of the side impact structure is performed at the mesoscale level, where each composite ply is modelled using 3-Dimensional (3D) reduced integration brick elements (C3D8R), using an explicit formulation within the software package Abaqus. An intralaminar damage model, based on the initial work of Faggiani and Falzon [1], and later adapted to 2D woven materials, is used to model damage initiation and propagation within the 3D ply elements. The interlaminar region between plies is modelled using the Abaqus® in-built cohesive surface behaviour.

This work evaluates the potential for using mesoscale damage models to simulate the progressive crushing of real industry-level components. The numerical results are assessed on the quantitative and qualitative accuracy of the simulation when compared to experiments.

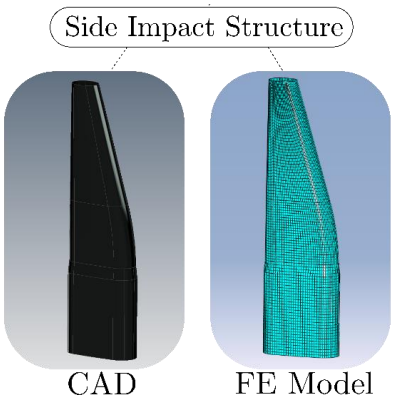

Figure 1 - *F1 Side Impact Structure schematic*

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, Intralaminar fracture toughness and crack resistance curves for FRPs under high rate loading

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Abstract To enable the reliable simulation of highly dynamic loading events (e.g. crash, foreign object impact), the strain rate sensitivity of the material properties should be known. Under dynamic loading conditions, no standardized tests exist to measure neither the elastic properties, nor the strength, nor the fracture toughness.

Taking into account that automotive and aeronautical polymer composite structures are subjected to dynamic loading scenarios (e.g. crash, foreign object impact), strain rate effects should be captured by advanced composite material models to predict initiation and evolution of damage accurately. The strain rate sensitivity of the stiffness and strength components of polymer composites has been intensively investigated and reviewed over the last decades. In addition, the experimental investigation of the dynamic interlaminar fracture toughnesses has received significant attention, motivated by the need to understand the delamination damage within composite laminates after low-energy impact.

In contrast to the interlaminar fracture modes, very little is known regarding the effect of dynamic loading on the energy intensive intralaminar fiber failure modes. Therefore, there is the need to develop experimental methods to measure the intralaminar fracture toughness in a dynamic loading scenario.

In the presented work, a methodology to measure the mode I intralaminar R-curve in compression is proposed to the case of dynamic loading. This approach uses the relations between the size effect law and the energy release rate (ERR) and the R-curve. The method does not require the optical measurement of crack length, whose determination is found to be a main source of errors in fracture mechanic tests, and is particularly critical for high loading rate experiments, where high speed cameras with reduced resolution are used. The dynamic tests are conducted on a split-Hopkinsonbar (SHB), which is a widely-used setup for dynamic fracture tests.

Double-edge notched compression (DENC) and tension (DECT) specimens are used for the determination of the size effect law. This specimen type is well suited for SHB testing, as it is found to be nonsensitive to complex wave deflections that might cause undesirable mixed mode stress state during the loading of the specimen.

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An experimental study on the fracture behavior of different aluminium alloys subjected to ballistic impact

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Abstract: Armour materials are used to provide protection against different threats in the battle field. Aluminium alloys are preferred as potential light armoured candidate material owing to their high strength-to-density ratio, good energy absorption capability, ease of manufacturing and excellent corrosion resistance properties. Ballistic impact is an immensely localized process and heat generated during such severe and rapid impact induces local thermal softening and microstructural instability. Therefore, it is imperative to investigate the fracture behavior of the material after projectile impact in order to understand its ballistic performance. The present work thus describes and analyses the experimental results pertinent to the ballistic behavior of six different series of commercially available aluminium alloys namely AA 2024, AA 2519, AA 5059, AA5083, AA 6061 and AA 7017 plates against 7.62 mm lead projectiles. These results include the observation of the damage area at the front of the aluminium alloy plates. The microstructures and micro-hardness values along the projectile penetration path have been investigated to understand the material deformation behavior. Post ballistic microstructure points out towards an adiabatic shear band induced crack formation and eventual fracture of the material. From the ballistic testing experiments, it is observed that AA-7017 plates display higher ballistic resistance among the tested aluminium alloys. The ballistic performance of the aluminium alloy plates has been correlated with their respective mechanical properties and post ballistic microstructure.

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VHCF behavior of a high strength crankshaft steel

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Abstract: Many industrial components are designed for a fatigue life that exceeds 10^6 cycles. Crankshafts are one of the main four stroke engine structural parts that are subjected to very high number of cycles. Therefore, it is a component subject to Very high cycle fatigue (VHCF). VHCF tests have become viable due to the existence of piezoelectric actuated fatigue testing machines that apply high frequencies (20kHz), thus enabling one to evaluate the fatigue behavior in a region beyond what is considered as infinite fatigue life. The fracture surfaces corresponding to fatigue failure in this region may present specific characteristics where crack initiation could appear on inclusions and fatigue crack growth is characterized as fish-eye and fine granular area (FGA). Ultrasonic fatigue tests were carried out on a crankshaft steel` specimens; the crankshaft failed in service. Experimental tests were carried out under a loading ratio R= -1 in order to determine the material fatigue strength. The fatigue fracture surfaces were analyzed and the fish-eye morphology as well as possible FGA were detected in some specimens. Based on this, stress intensity factor (SIF) calculation for internal cracks was performed, thus obtaining values of $K_{max,\,fish-eye}$ and $K_{max,\,FGA}$.

Keywords: very high cycle fatigue, crankshaft, fatigue life, fish-eye, fine granular area, stress intensity factor

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Fatigue testing of cruciform specimens under VHCF

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Abstract: The reliability of any given structure or machine subjected to dynamic loads is mainly depended on detailed fatigue study of the applied materials. As the demand for higher fatigue lives with more complex stress applications increases so does the necessity for new and more complex fatigue testing methods. Since it was proven that there´s no fatigue limit in certain conditions, ultrasonic fatigue tests were developed for the study of the life beyond that point, the Very High Cycle Fatigue (VHCF) regime. In these tests, specimens are subjected to stress cycles in frequencies as high as 20 kHz. Most ultrasonic fatigue tests apply uniaxial stresses but it is important to be able to apply complex multiaxial loading since most components are subjected to a complex stress cycle. In this work cruciform specimens are used in an ultrasonic fatigue machine, see fig. 1. Two different geometries are in study capable of inducing a biaxial stress combination axial-axial in the high frequency of ultrasonic fatigue tests. The geometries are subjected to an experimental analysis to understand if they are working as intended. Based on achieved experimental results, some conclusions are drawn.

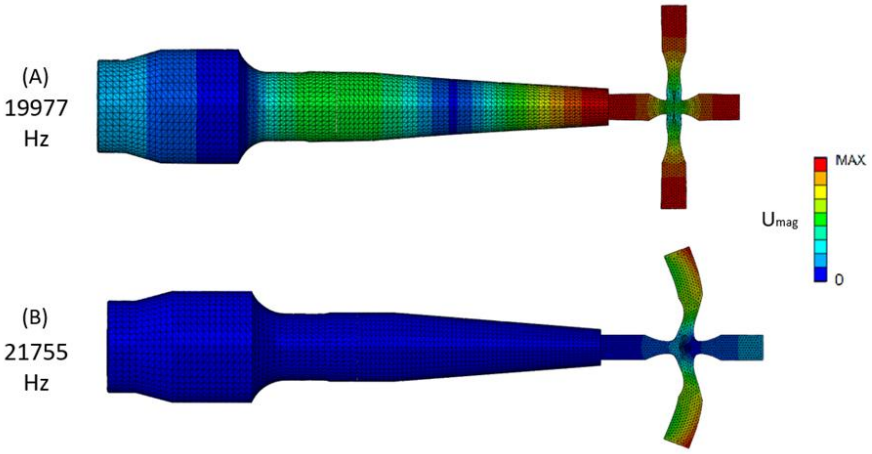

Figure 1 - *Resonance mode shapes with the system components for the C-T specimen*

KEYWORDS: Cruciform specimens, in-plane biaxial stresses, Ultrasonic frequencies, VHCF, experimental tests

Experimental studies of 3D woven composites interweaving types effect on the mechanical properties of a polymer composite material

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Abstract. Composite materials have a set of properties and features differ from traditional structural materials, in particular provide ample opportunities both to improve existing designs of the most diverse purposes and to develop new designs and technological processes. Three-dimensional spatial reinforcing fillers are used for high-performance composite materials in such industries as aerospace, engineering, aircraft and shipbuilding, metallurgy, nuclear and power engineering. Multilayer carbon fabrics of bulk weaving are used as a reinforcing material for carbon plastics, working in difficult and harsh conditions of high-speed aerodynamic flow, vibration and high temperatures.

Within the framework of the complex tests, experimental studies of tensile, tensile/ compression of samples with a hole, bent beam four-point bending, impact and compression after impact, non-uniform separation, and shear in the plane were carried out. A total of 6 weave patterns of 3D woven performs and two types of layered samples reinforced in the transverse direction are considered. This paper presents experimental studies of tensile strain of solid samples and with a hole.

Using the Vic-3D digital optical system, the deformed state of samples of 3D woven polymeric composite materials based on preforms in the hub area is analyzed. With the help of the video system the evolution of the deformation fields was recorded, the nature of the field heterogeneity was assessed, the mechanical characteristics of the material were determined. The fields obtained showed a non-uniform strain distribution and dependence on the types of reinforcing fibers. In evaluating the mechanical characteristics, materials with the highest elastic properties are noted.

In the course of the study, it was found that the crack in the sample extends perpendicular to the axis of the load, which corresponds to the numerical patterns of the strain distribution fields. It was also noted that the strain distribution fields obtained using the digital video system are heterogeneous and asymmetric, which is associated with the heterogeneity of the microstructure of the sample material surface. Large deformations are concentrated in the areas of the recesses, while smaller ones - around the recesses.

The morphology of destruction and distribution of deformation fields shows the destruction of composite samples with a hole is associated with the breakage of fiber bundles caused by the technological processing of the material in the immediate vicinity of the hole. Numerical fields of strain distribution, as well as the direction of crack propagation are close to the experimental results, while the study did not take into account the microstructure of the sample material. Thus, we can conclude the methods used in this study are able to accurately predict the location and direction of development of defects.

This work was carried out in Perm National Research Polytechnic University using the equipment of the Centre of Collective Usage «Complex test and diagnostic equipment for study of structural and functional materials properties under complex thermomechanical impacts» (http://www.ckp-rf.ru/ckp/353547/), with supported by the Russian Foundation for Basic Research (project No. 18-01-00763 A).

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Identification of material properties of a laminated plate from measurements of natural frequencies and modal rotations

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Abstract This paper presents a method for identification of material constants of a laminated composite plate. An optimization problem, with an objective function relating experimental and numerical natural frequencies, is formulated and solved. Three optimization algorithms were applied in this study for comparison purposes: (1) particle swarm, (2) genetic, and (3) pattern search algorithms. The identified material constants were validated by comparing modal rotations measured with shearography with those computed by finite element analysis.

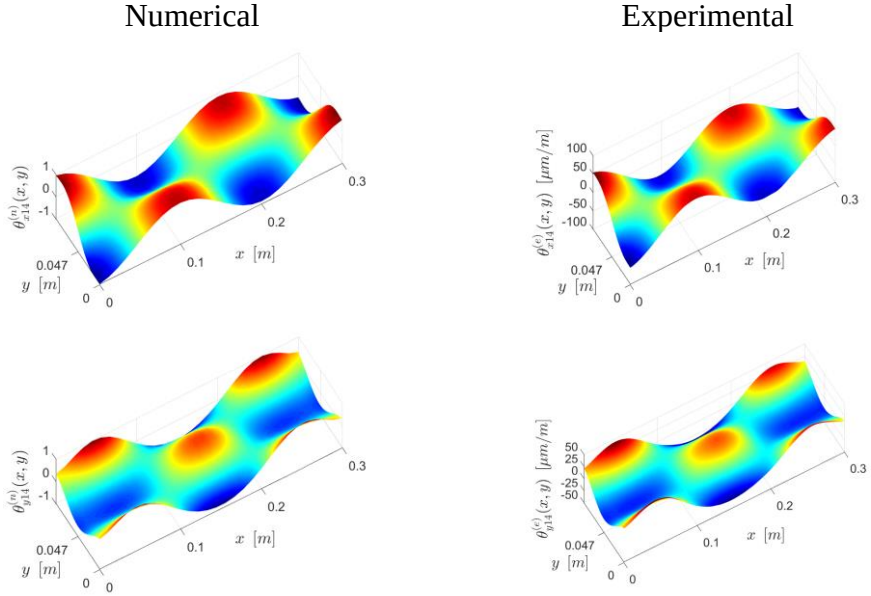

Figure 1 – Comparison between the numerical and experimental modal rotations.

, Behavior of short concrete cylinders partially confined with GFRP composites

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Abstract: The confinement with Glass Fiber Reinforced Polymer (GFRP) composites of the concrete columns is effective in increasing their capacity as demonstrated by many authors in the field, but few studies dealt with partially wrapped columns. The main objective of this work is to study the influence of the partially confinement with Glass Fiber Reinforced Polymer (GFRP) composites on the behavior of the concrete cylinder under axial compressive load. Different heights of the confined area are considered in order to follow the evolution of the global mechanical response of the cylinder according to the parameter 'x / h' which represents the ratio of the height of the confined zone to the total height of the cylinder. The numerical results show that the partial confinement increases the ultimate stress of the confined short concrete cylinder and influences the mode of rupture. The confrontation of the numerical results with the experimental one show a good concordance.

Keywords : partial confinement, composite GFRP, compression, numerical analysis.

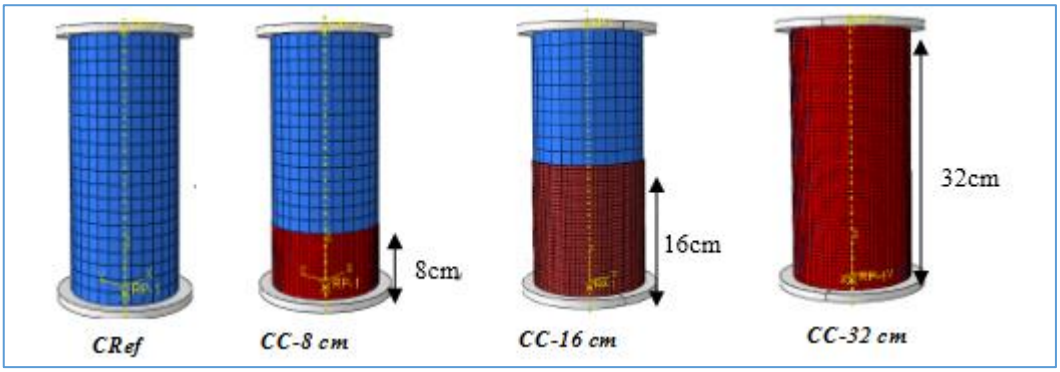
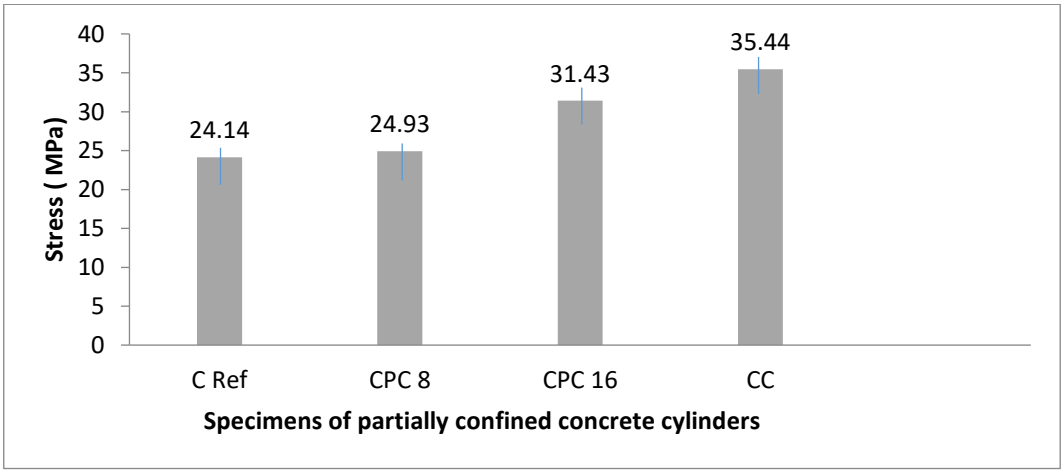


Fig .1. *Specimen considered*



, **Fig .2**. *Histogram of stress values of specimens used*

Digital image correlation with a moving camera using structure from motion calibration

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Abstract The application of digital image correlation (DIC) in structural monitoring can benefit from the use of remote controlled image acquisition systems such as unmanned aerial vehicles (UAVs) in cases where the structure to be assessed is of difficult accessibility. However, this configuration does not always allow normal camera calibration procedures to be followed.

In this work, a camera is manually moved around an object prepared with a speckle pattern, in a reference state and later in a loaded state, in an attempt to emulate the behaviour of a UAV. A structure from motion (SfM) algorithm is applied to the captured images in order to obtain camera calibration parameters for each image using features found in the object's surroundings. An image pair from each state is chosen and 3D DIC is performed on the object using the previously obtained calibration.

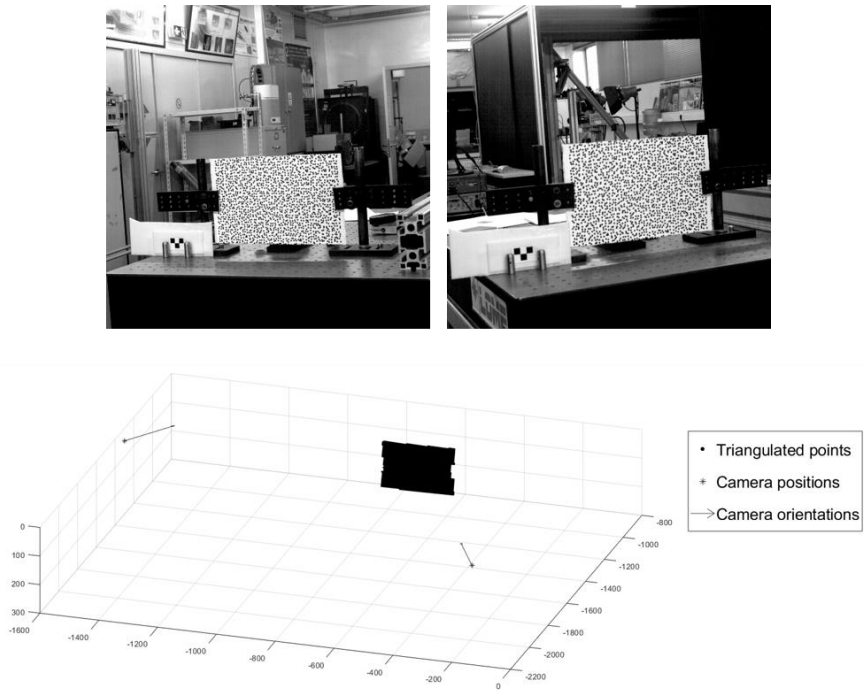

Figure 1 – *Images of the DIC specimen from the video taken by the moving camera and corresponding camera positions and orientations obtained through the calibration algorithm*

, Experimental and numerical studies on the behaviour of polymer-matrix fibre-reinforced composites subjected to soft impact loading

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Abstract This paper presents detailed experimental and numerical studies on the behaviour of composite laminates subject to impact loading by soft objectives. In this research, gas-gun experiments employ woven carbon fibre reinforced poly (ether-ether ketone) (CF/PEEK) and gelatine projectiles to study the response of composite laminates under soft impact loading. In addition, the woven carbon fibre reinforced epoxy (CF/epoxy) composite specimens were also tested using the same gelatine projectiles in investigate the effects of the matrix system on the impact response of composite laminates. A high-speed camera is employed to capture the deformation of the projectiles and a three-dimensional (3D) Digital Image Correlation (DIC) system is used to record the deformation of the impacted composite specimens. A numerical finite-element (FE) model is developed to simulate the soft impact on the composite laminates. Good agreement has been shown between the predictions from using the FE model and the experimental results.

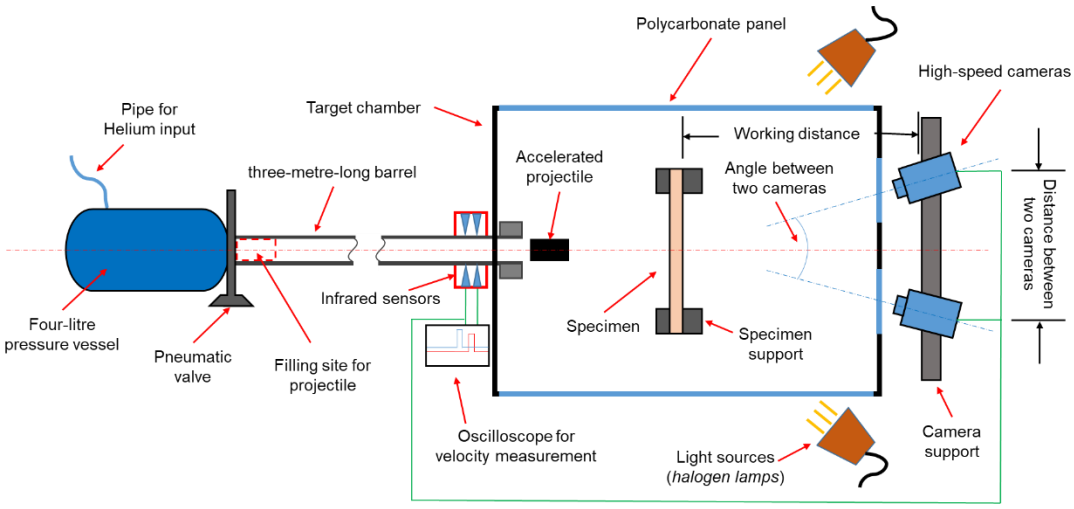

Figure 1 - *Schematic of the experimental set-up for the gas-gun impact tests.*

, **Effect of medium carbon steel microstructure on tensile strength and fatigue crack growth**

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Abstract

Purpose–The purpose of this paper is to evaluate the effects of medium carbon steel microstructure on the tensile strength and fatigue crack growth (FCG) behavior.

Design/methodology/approach–To achieve this aim, four different heat treatment methods (normalizing, quenching, tempering at 300°C and tempering at 600°C) were considered. Microstructural evolution was investigated by scanning electron microscopy. FCG rate tests were conducted on the resultant microstructures with compact tension specimens at room temperature by a standard testing method.

Findings–The results show that the normalized microstructure had the largest number of cycles to failure, indicating a high fatigue resistance, followed by the as received, tempered at 600°C, tempered at 300°C and quenched microstructure.

Originality/value–The paper shows the influence of the microstructure on the fatigue-propagation behavior with the definition of the Paris parameters of each heat treatment condition.

Keywords Heat treatment, Microstructure, Fatigue crack growth, Medium carbon steel

Fatigue Testing at 1000Hz Testing Frequency

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Abstract

There is no infinite fatigue life. In the recent decades we learned that fatigue testing with higher number of load cycles is required in some areas. The development of faster testing techniques e.g. Ultrasonic systems testing on 20kHz have allowed the conduction of many research activities in the giga cycle regime in the recent decades. In 2014 RUMUL could present a new resonant fatigue testing machine, with a testing frequency of 1000Hz. The dynamic load of maximum 50kN peak-peak is produced with an electromagnetic system. The static portion of the load is provided by two mechanical spindles, the maximum load of the system is +/- 50kN. Any load ratio can be selected. Flat and round specimen types that are normally used in fatigue testing can be used. The actually tested material volume is larger than the material volume that is tested on ultrasonic systems. The new testing machine offers new possibilities for investigations of material properties in the very high cycle fatigue (VHCF) regime.
In the past years the new testing machine was intensively used in several laboratories in Germany for example at the laboratory of the Fraunhofer institute IWS Dresden in Germany. Some effects of the 1000Hz testing frequency on the fatigue behavior of the material have been observed. This paper provides a summary how the frequency of an alternating load affects fatigue life of a material. And it highlights some of the found frequency related effects on fatigue strength. Some examples of heating up of the specimen related to the 1000Hz testing frequency are shown. Normally continuous fatigue testing is possible, without stopping for cooling down the specimen.

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Keywords: New Resonant Fatigue Testing Machine; Giga cycle (VHCF); Frequency effects

1. INTRODUCTION

‘‘There is no infinite fatigue life in metallic materials” [1]. Studies on damage mechanism on higher number of load cycles, in the range of up to 1010 cycles and more could well proof the finding published by Claude Bathias and others. Thanks to the development of faster testing technics and the shortening of testing time a large number of basic research activities took place in the recent decades. Ultrasonic fatigue testing systems work on the resonant frequency at about 20kHz, and require relatively small specimens with a specific geometry. Ultrasonic fatigue studies showed that a fatigue limit in the traditional sense does not exist in the gigacycle regime. Cracks may occur subsurface or on the surface, and may start for example from inclusions in the material [1].

Subsequent with higher testing frequency, an old question of fatigue testing is high-lighted and cannot be neglected: “What is the effect of the testing frequency on fatigue life?” Testing on very high testing frequency may lead to different damage mechanism than under real loading condition for example of an engine component.

Since inclusions and imperfection play an important role in VHCF the manufacturing process has a significant effect on fatigue life in the Gigacycle regime. Particularly for relatively inhomogeneous materials the testing of material volumes that represents the scatter of the manufacturing process is a concern.

In 2014 RUMUL could present a new resonant fatigue testing machine, with a testing frequency of 1000Hz. The dynamic load of maximum 50kN peak-peak is produced with an electromagnetic system, similar to established resonant fatigue testing systems which typically run on testing frequencies from about 40 up to 250Hz. The static portion of the load is provided by two mechanical spindles, the maximum load of the system is +/- 50kN. Any load

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ratio can be selected. Flat and round specimen types that are normally used in fatigue testing can be used. The new testing machine offers new possibilities for investigations of material properties in the very high cycle fatigue (VHCF) regime. Compared to other systems used in the field of VHCF testing the RUMUL GIGAFORTE provides several advantages. The size of the machine is smaller and energy consumption less compared to a servo hydraulic system. The actually tested material volume is larger than the material volume that is tested on ultrasonic systems. The testing frequency of 1000Hz allows normally continuous testing, without intermittently stopping the test for let the specimen cool down.

In the past four years the new testing machine was intensively used for example at the laboratory of the Fraunhofer-Institut fürWerkstoff- und Strahltechnik IWS in Dresden in Germany. It is used for testing material samples and small components as well. Some effects of the 1000Hz testing frequency on the fatigue behavior of the material were observed [2]. Recently the IWS laboratory developed a small salt spray chamber and mounted it on the GIGAFORTE to perform fatigue testing under corrosive atmosphere.

2. Effects of the loading frequency on fatigue life

What is the effect of the frequency of an alternating load on fatigue life and fatigue testing? This question is probably present since beginning of fatigue testing in any area of fatigue testing such as axial loading or rotating bending; on room or elevated temperature or corrosive environment. In literature several investigations can be found that show an effect of the testing frequency on fatigue life, particular on very high testing frequencies and relatively high load. For lower frequencies the effects can be neglected very often, however the sometimes unknown magnitude of some effects led to a quite conservative approach of limiting the testing frequency in some areas of fatigue testing. The frequency effects can be divided in three areas: Temperature and environment as extrinsic factors and strain rate as intrinsic factor [2, 3]. The effects may superimpose, and affecting fatigue life in the same or opposite direction.

2.1. Temperature

A higher material temperature reduces usually the fatigue life in a similar way as the ultimate strength of a material is related to the temperature. And some materials show a temperature depending crystallographic transformation that affects the material properties and fatigue life. Maintaining the specified temperature range is therefore a basic requirement for fatigue testing.

A material specific basic damping is always present when deforming a solid material. Microscopic plastic deformation during cyclic loading leads to additional damping and it is almost completely transferred to heat. The damping energy and corresponding heat that is produced per load cycle and volume is constant for an even axially loaded specimen. The produced heat per time is proportional to the frequency. The resulting material temperature depends as well on the present heat losses, for example the heat flow to the fixture and to the ambient atmosphere. Convectional cooling can be used to control the temperature during testing.

Some material do not show the above described linear relation between temperature and testing frequency, with higher frequency the temperature does not increase as expected [4]. This finding may point to hardening (resp. softening) mechanism which can be strain rate related (see section 2.3)

2.2. Environment

There are time related mechanisms such as oxidation, corrosion or creep that may play a role for the formation of a new surface during crack initiation and propagation. Depending on the relevance of such mechanisms a significant frequency effect can be expected. For example, it is reported that some investigations show a significant frequency dependency of aluminum alloys on fatigue life. The aluminum alloy AW-5083 shows almost now frequency effect at 20 kHz on fatigue life in inert atmosphere but in air [3].

2.3. Strain Rate

The strain rate is proportional to the testing frequency. However during loading in resonant condition the strain rate is not constant, it follows a sinusoidal function. It is thought that the strain rate of irreversible deformation could

affect fatigue life significantly. A relevant effect can be expected when the highest strain is present during the load cycle. Therefor the relation between frequency and a possible effect on fatigue strength is non-linear.

An influence of the testing frequency at 20 kHz on fatigue life could be found on quenched and tempered steel 50CrMo4 depending on the strength of the material. It was concluded that the found correlation of fatigue life and testing frequency is related to the strain rate and is typical for cubic body centred metals. The frequency effect is mainly seen on the left side, of finite life of the S–N curve. [3].

For metastable austenitic steel (1.4301, AISI 304) a frequency effect related to the transformation of crystallographic structures was found during testing at 1000Hz with the GIGAFORTE. The analyses showed that higher amounts of strain-induced Martensite and lower plastic strain amplitudes are observed when the cyclic experiments are carried out at lower frequency, promoting higher fatigue strengths [2, 5].

3. Fatigue Testing with the GIGAFORTE

3.1. Fatigue life of steel 50CrMo4, 37HRC

Tests were carried out in cooperation with Hochschule Osnabrück - University of Applied Sciences on the RUMUL TESTRONIC (95 Hz), GIGAFORTE (1000 Hz) and an Ultra Sonic testing system (20 kHz). On 1000Hz round specimen with diameter 6mm and hour glass shape were used and tested at RUMUL. Compressed air cooling was used. On 1000Hz and on stress amplitude 500MPa and higher the heating up was significant and difficult to control. The tests show the fatigue life results that are gained on 1000Hz are within the population of the results of the tests carried on 95Hz or below, the latter is most likely related to the specimen heating up. The fatigue life results on 20 kHz are significantly higher, it is related to frequency and size effects [6] (as found in other investigations, see 2.3).

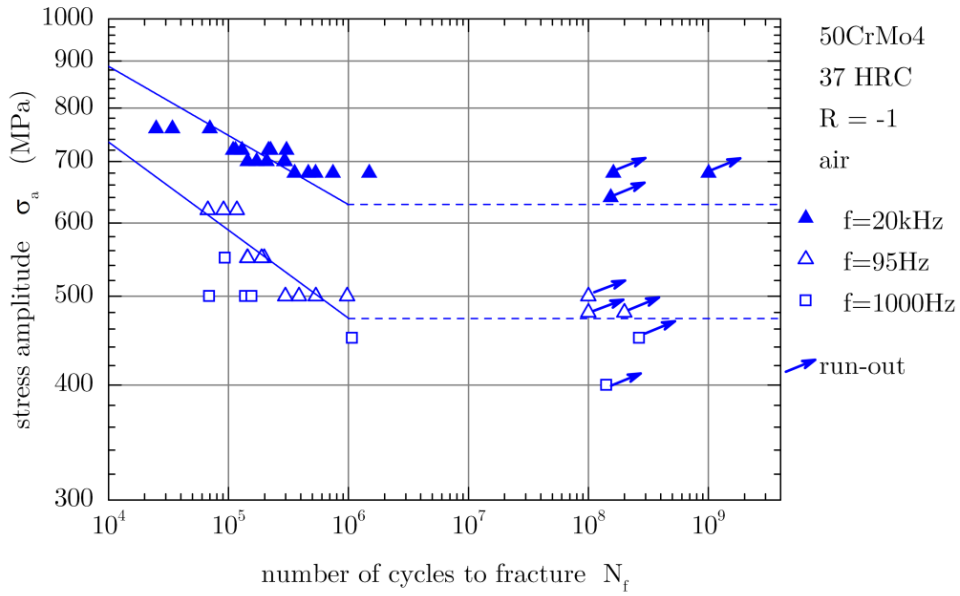

Fig. 1 Woehler diagram steel 50CrMo4 37HRC on 95Hz, 1000Hz, 20kHz testing frequency, A. Giertler 2019

3.2. Temperature records

RUMUL could look into heating up behavior of material samples in the last years. The specimens have been provided by interested laboratories. For Temperature recording a type K thermocouple was attached on the specimen. Compressed air was used to mitigate heating up if required. Load ratio was selected -1 for all tests.

Table 1. Temperature recordings of various materials during fatigue testing

Material	Specimen	Gauge diam.	Testing condition	Frequency	Load amplitude	Temperature

Nodular Iron	round, cyl. and hour glass, w. thread	7 mm	load increasing 0.2*106cycles / step compr. air cooling	1011 Hz	8.5 kN (220 MPa)	38°C
9% Cr-steel	round, hour glass, w. thread	8 mm	load increasing, 2*106cycles / step compr. air cooling	1024 Hz	18.6 kN (373 MPa)	26°C 54°C[1)]
Ti alloy	round, hour glass, w. thread	5 mm	const. load 106cycles / step no cooling	996 Hz	5.52 kN (280 MPa)	35°C
Ferritic steel HV30 ~ 220	round, cyl. w/o thread	8 mm	load increasing, 106cycles / step no cooling, (Fig.2)	1023 Hz	17 kN (337 MPa)	62°C[2)]

1) Cooling temporarily off

2) Temperature is not stabilizing, probably softening effect (see 2.3)

Table 2. Temperature recordings of high strength bolts during fatigue

Material	Specimen	Gauge diam.	Testing condition	Frequency	Load (amplitude)	Temperature	Cycle to failure
steel	flange head bolt	M9x1.25	Constant load Mean load 37.9kN	1006 Hz	8.0 kN	20.4°C	134’322
					7.5 kN	20.5°C	213’371
					7.0 kN	20.4°C	180’707

4. Summary and Outlook

The RUMUL GIGAFORTE is an efficient tool for testing very high number of load cycles in a reasonable time. Common specimen types and sizes can be used. Depending on material and load the specimen may heat up. The heating is usually low or moderate and can be mitigated with compressed air cooling, continuous testing is possible. The possibility to test on 1000Hz testing frequency may help to further evaluate frequency effects and further enhance the confidence on fatigue data in the high and very high cycle regime.

Next steps

- More HCF test (10^6 cycles and less) on high strength bolts for evaluation of the fatigue life results.
- VHCF testing (10^9 cycles and more) on fibre-reinforced composite materials cooperation with TU Dortmund/ Germany.

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6. The effect of different microstructures by heat treatment on the VHCF properties of low carbon steels. A. Giertler, K. Koschella, U. Krupp, Hochschule Osnabrück - University of Applied Sciences, Germany

Figures

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Technical data:	**RUMUL GIGAFORTE 50**
Max. peak value:	50 kN tension/compression
Max. dynamic load range:	50 kN (+/- 25 kN amplitude)
Max. static load:	+/- 50 kN
Max. dynamic stroke range:	0,2 mm (+/- 0,1 mm)
Test frequency:	approx. 1000 Hz *(+/- 3 %)*
Horizontal daylight:	400 mm
Max. vertical test space:	330 mm *
Control modes:	Load, Stroke, Acceleration
Sample types:	round up to M27x2 with and without tread flat, bending
Total weight:	approx. 1200 kg
Sound insulation cabin:	is required! (up to 120 dB) with cabin 80dB measured

Fig. 2 1000Hz Fatigue Testing Machine RUMUL GIGAFORTE with small sound enclosure

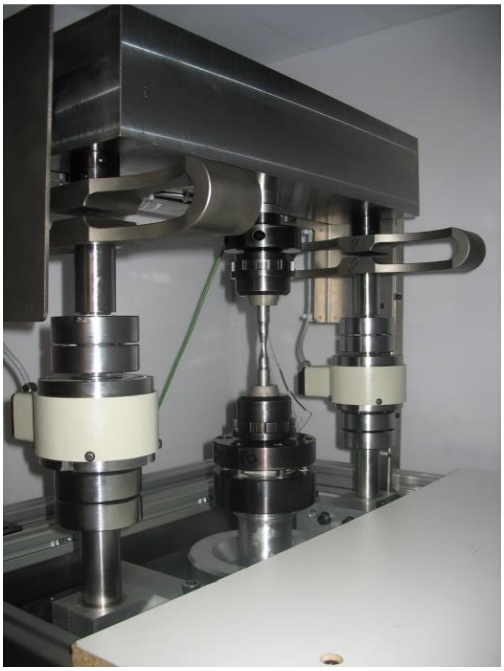

Fig. 3 RUMUL GIGAFORTE, round specimen without thread, thermocouple attached with tape.

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Elastoplastic deformation and destruction of structural steel under biaxial loading conditions

Anastasiya V. Lykova, Artem V. Ilinikh, Valery E. Wildemann, Tatyana V. Tret*yakova*

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Abstract. Currently, relevant studies in the field of predicting the structural materials and machine parts durability. The work is devoted to the mechanical behavior laws study and prediction of EP517SH steel (chemistry: C - 0.13%; Cr - 12.5%; Si - 0.05%; Ni - 2.05%; Mo - 1.50% , W - 0.70%; Nb - 0.20%; V - 0.20%) cyclic durability with low-cycle fatigue under biaxial loading conditions.

Experimental studies on low-cycle fatigue under conditions of biaxial loading with simultaneous action of tension-compression and torsion of thin-walled tubular specimens with different forms of loading were carried out. The methodological issues of tensile testing, torsion and the joint action of tensile with torsion at normal and elevated temperatures are considered. For low cycle fatigue tests using servohydraulic testing system Instron 8850 was employed with using Epsilon mounted two-axis deformation temperature sensor. A two-axis extensometer made it possible to carry out cyclic tests and realize various rigid loading trajectories with proportional and non-proportional changes in axial and shear deformations. During the test a Dynacell biaxial load cell was used with maximum measured loads of ± 160 kN in tension or compression and ± 1 kNm in torsion. For tests at elevated temperatures, a high-temperature furnace SF 1770 was used. Experiments on low-cycle fatigue at normal and elevated temperatures of structural steel EP517SH were carried out in the hard loading mode. The tests were carried out according to the following loading schemes: proportional change of axial and shear deformations (simple loading with triangular and M-shaped cycle forms, respectively), non-proportional change of axial and shear deformations (complex loading).

Thus, experimental data were obtained on the resistance of low-cycle fatigue at various cycle parameters, proportional and complex loading of EP517SH steel at normal and elevated temperatures. The results of the test were processed to analyze the possibility of using the criteria for the destruction of the energy type for different schemes of cyclic deformation. Experimental data for a structural alloy has been described using equivalent parameters (stress intensity), which make it possible to analyze the possibility of using damage accumulation models to estimate cyclic durability under biaxial loading.

The work was performed at Perm National Reseafch Politechnic University, Center of Experemental Mechanics, and was supported by RSF project No. 16-19-00069.

Mechanical performance of Additive Manufacturing: Fundamentals, results and a real case study

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[1]*AM Technical Manager, Renishaw Ibérica*

[2]*Chief Technical Officer - Materials & Processes, CATEC*

Abstract Additive Manufacturing processes such as laser powder bed melting are being qualified as a valuable manufacturing route in aerospace and biomedical sectors together with distinct niche-applications in different industries. During the last years, commercially available platforms have been optimized to improve quality and boost productivity. Interaction between laser(s) and powder has been optimized and laser control enhanced, which has led to reduced defects in AM parts. Current fatigue results of multi-laser AM technology and main fundamentals are shown. Furthermore, a real aerospace application is presented.

Incremental Hole Drilling Residual Stress Measurement in Thin Aluminum Alloy Plates Subjected to Laser Shock Peening

J.P. Nobre, C. Polese and S. van Staden

[1]Main Author's affiliation, full address and e-mail [size 12, centered, italic, times]

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Abstract Residual stresses in aluminum alloy 7075 plates, with different thicknesses and treated using the same laser shock peening (LSP) parameters, are determined by the incremental hole drilling technique (IHD) using the integral method. The experimental results are benchmarked against other residual stress measuring methods used as reference, such as neutron diffraction (ND), energy dispersive X-ray diffraction (EDXRD) and laboratory X-ray diffraction (XRD). A numerical simulation by the finite element method is carried out to determine the expected strain relaxation errors due to the thin thickness of the samples, falling outside the limits preconized by the ASTM standard, and the feasibility of a correction procedure to still use the ASTM standard to determine non uniform residual stresses in thin samples is discussed and validated. The validation is achieved by comparing the IHD corrected results with the results obtained by the reference techniques and with the IHD results based on the integral method using necessary calibration coefficients for the actual thickness of the samples, previously determined by the finite element method.

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New monitoring solutions for large civil engineering structures

Project MEGE

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Abstract This work presents the ongoing project aiming at the reinforcement of the monitoring system to assess the structural health of the runway extension and its maritime protection, a berm breakwater that protects the foundation columns of the airport runway and a nearby breakwater that protects the search and rescue aid station, at Madeira Airport.

Image-based monitoring systems will be implemented in both structures. On two of the beams supporting the runway, in the touchdown zone, digital image correlation will be performed in order to quantify the deflection of the beams caused by the impact of the landing. In the same area, accelerometers and fiber optic strain gauges will be installed in order to give supplementary information and allowing a comparison with the results from the image-based monitoring system.

The berm breakwater and the search and rescue breakwater, which are subject to erosion and may therefore suffer long-term structural evolution, will be regularly inspected by an unmanned aerial vehicle carrying a camera, for 3D profile acquisition and comparison through time.

Figure 1 – *Madeira's airport runway foundation columns and breakwaters*

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,Fatigue & fracture crack paths generated by manufacturing-induced microstructural & strength anisotropy in cold drawn pearlitic steels: (a) In the conceptual frame of Maurits Cornelis Escher and Johann Sebastian Bach; (b) An Orteguian approach and a tribute to Fray Luis de León's "decíamos ayer"

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Abstract This paper analyses both fatigue & fracture crack paths generated by manufacturing-induced microstructural & strength anisotropy in cold drawn pearlitic steels, on the basis of their microstructural evolution during manufacturing by multi-step cold drawing that produces slenderizing and orientation of the pearlitic colonies, together with densification and orientation of the Fe/Fe3C lamellae, reviewing previous research by the author and co-workers on fracture behaviour in inert and aggressive environments in the presence of crack and notches, with focus on hydrogen embrittlement. Results demonstrate the key role of manufacturing-induced microstructural anisotropy (orientation of the two microstructural levels of pearlitic colonies and ferrite/cementite lamellae as a consequence of the progressive/repetitive cold drawing) in the fatigue & fracture crack paths, thus producing crack path deflection/deviation/branching with mixed-mode crack growth and associated anisotropy of fatigue & fracture resistance and its linked anisotropic fatigue & fracture behaviour (strength anisotropy), allowing the definition of a directional toughness depending on the specific crack path with its propagation direction. From the point of view of the analysed material (progressively cold drawn pearlitic steel, a hierarchically structured material with colonies and lamellae), the present scientific work is related to the conceptual frame of Maurits Cornelis Escher and Johann Sebastian Bach. In addition, the paper represents an orteguian approach (on the basis of the circumstance formulated by José Ortega y Gasset) to the problem of fatigue & fracture of progressively cold drawn pearlitic steel and a tribute to Fray Luis de León´s "decíamos ayer".

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, Post-fire Performance of Novel Flame Retardant Composites

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Abstract

Apart from the improvement for flame retardant properties of polymer composites, the effect of fire on the mechanical performance is essential for composite in load-bearing structure. This research investigated the effect of novel intumescent mats (1# and 2#) with different compositions on the post-fire performance of carbon fibre reinforced composites. The sandwich structure was designed for composites where 1# or 2# mat was covered. A significant reduction in the peak heat release rate (PHRR) and total heat release (THR) was observed from the cone calorimetric data, and carbon fibre reinforced composite with 1# mat showed the lowest value of 148 kW/m^2 and 29 MJ/m^2 for peak heat release rate and total heat release, respectively. In addition, a minor influence on initial mechanical properties was observed due to the variation of composite thickness and resin volume in the composite. As can be seen from Figure 1, the post-fire properties of composite were characterised, and the 1# mat presented better retention for flexural strength and modulus of composites. With the comparison between simulated and measured data, the feasibility of two-layer model was confirmed to predict the post-fire performance of composites and reduce the reliance on the large amounts of empirical data.

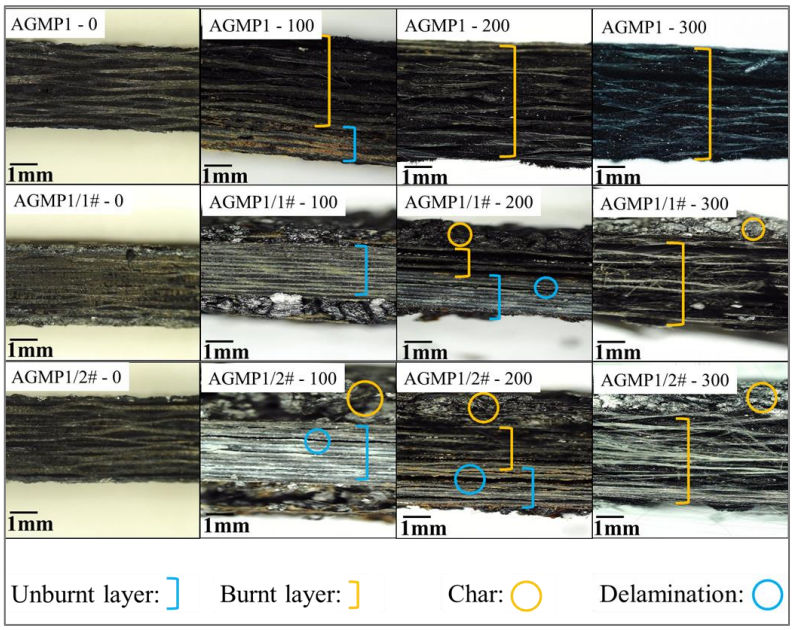

Figure 1 - *The cross-section view of fire damaged composites after 50 KW/m^2 heat fluxes.*