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MON, 10:05 - 10:40	PLENARY LECTURE II	Room Funchal
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TUE, 10:05 - 10:40	PLENARY LECTURE IV	Room Funchal
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Ref:	Title and Author (s)		Ref:	Title and Author (s)		Ref:	Title and Author (s)		Ref:	Title and Author (s)		Ref:	Title and Author (s)	
#174	On the Nonlinear Elasto-Plastic Behavior of AA6061-T6: Experimental and Numerical Implementations Behzad V. Farahani, Jorge Belinha, Paulo J. Tavares, Pedro Moreira		#96	Fatigue damage in spline couplings: numerical simulation and experimental validation Francesca Curà, Andrea Mura, Federica Adamo		#25	Fatigue strength and fracture mechanics Zerbst, U., Madia, M., Vormwald, M.		#108	Ultra-Low Cycle Fatigue at Complex Loading Scenarios Sven Nagel, Peter Knödel, Thomas Ummenhofer		#71	Stress state analysis and optimization in the vicinity of the sensor of SMART-material N.A. Kosheleva, V.P. Matveenko, I.N. Shardakov, A.Y. Fedorov	
#189	Impact response of polyurethane and polystyrene sandwich panels Oana Mocian, Dan Mihai Constantinescu, Marin Sandu, Ştefan Sorohan		#161	Static and fatigue behaviour of Sikadur®-30 and Sikadur®-52 structural resins/adhesives M. Rodrigues, J.A.F.O. Correia, B. Pedrosa, A.M.P. De Jesus, C. Rebelo, M. Calvente, P. Moreira, R.A.B. Calçada, A. Fernández-Canteli		#39	Numerical modeling and testing of mechanical behavior of AM Titanium alloy bracket for aerospace application Eugenio Brusa, Raffaella Sesana, Enrico Ossola		#129	Anisotropy and size effect in tensile mechanical properties of Al-Cu-Li 2198 alloy Theano N. Examilioti, Benjamin Klusemann, Nikolai Kashaev, Stefan Riekehr, Josephine Enz, Nikolaos D. Alexopoulos		#101	Impact force reconstruction in composite panels Giulia Sarego, Mirco Zaccariotto, Ugo Galvanetto	
#103	Evaluation of the fretting wear damage on crowned splined couplings Francesca Curà, Andrea Mura		#138	Creep characterization of service-exposed Grade 91 steel in USC Plant Woo-Gon Kim, Jae-Young Park, Hyeong-Yeon Lee, Hyun-Uk Hong		#51	Fatigue strength of welded joints under multiaxial non-proportional loading Sabrina Vantadori, Andrea Carpinteri, Filippo Berto, Joel Boaretto, Giovanni Fortese, Felipe Giordani, Ignacio Iturrioz, Camilla Ronchei, Daniela Scorza		#143	The study of evolution of physical and mechanical properties of metals under gigacycle fatigue A. Prokhorov, M. Narykova, A. Kadomtsev, V. Betechtin, O. Plekhov, O. Naimark		#162	Failure Analysis Of Composite Repaired Pipelines With An Inclined Crack Under Static Internal Pressure Amr A. Abd-Elhady, Hossam El-Din M. Sallam, Muhammad A. Mubaraki	
#325	Thermal Analysis of the ITER's Collective Thomson Scattering System B. Pereira, R. Ferreira, B. Gonçalves, S. B. Korsholm		#197	Influence of corrosion morphology in fatigue strength of bolted joints Zampieri Paolo, Andrea Curtarello, Emanuele Maiorana, Carlo Pellegrino, Nicola De Rossi, Gianpaolo Savio, Gianmaria Concheri		#56	Crack path prediction in fiber reinforced composites Paul Judt, Andreas Ricoeur, Jan-Christoph Zarges, Maik Feldmann, Hans-Peter Heim		#328	Strain rate dependency of aeronautic aluminium alloys AA7475-T7351 and AA2124-T851 Sahand Pourhassan, Pedro Moreira, Marina Plöckl, Hannes Körber, Dominik Schüler, Nathalie Toso		#228	Anomaly detection in composite elements using Lamb waves and soft computing methods Piotr Nazarko, Leonard Ziemiański	
#326	Thermal structural analysis of ITER's Collective Thomson Scattering launcher mirror R. Ferreira, B. Pereira, R. Rêgo, B. Gonçalves, S. B. Korsholm		#7	Fracture mechanics based estimation of fatigue lives of laser welded joints Rakesh Goyal, El-zein Mohamad, Sergey Bogdanov, Gregory Glinka		#81	Brittle Fracture Modeling for Steel Structures operated in the Extreme Valeriy Lepov, Albert Grigoriev, Mbelle Samuel Bisong, Kyunna Lepova		#180	Assessing the Irradiation Damage using Dislocation Based Crystal Plasticity Model for BCC Materials Kulbir Singh, C. Robertson, A.K. Bhaduri		#291	Evolution of a fracture mechanism in a polymeric composite subjected to fatigue with the self-heating effect Andrzej Katunin, Angelika Wronkowicz	
#209	Optimization of machining parameters to improve the surface quality João Eduardo Ribeiro, Manuel Braz César, Hernâni Miguel Lopes		#150	Moisture absorption effect on the stress distribution of the cross-ply Khodjet-Kesba Mohamed, Benkhedda Amina, Adda Bedia El abbes, Boukert billel		#311			#139	Study of the spatial-time inhomogeneity of inelastic deformation and failure in bodies with concentrators by using the digital image correlation and infrared analysis Tatyana Tretyakovar, Valery Wildemann		#225	Stable crack growth in composite laminates under various stiffness of the loading system Tretyakov M.P., Wildemann V.E.	

Tue	Session 5A 14:00-15:30	Room Funchal
TOPIC: Symposium G Chair: Hernani Lopes		
Ref:	Title and Author (s)	
#26	Landing Gear Structural Health Monitoring (SHM) Chad Forrest, Clint Forrest, Doug Wiser	
#86	Fatigue crack monitoring using plastic optical fibre sensor Dong Yang, Wei-xin Ren, Dan Li, Yi-ding Hu	
#29	Cognitive Sensor Technology for Structural Health Monitoring Alexander Serov	
#104	Threshold Selection in POT Method for the Extreme Value Extrapolation of Bridge Strain Due to Vehicle Loads Xia Yang, Jing Zhang, Wei-Xin Ren	
#133	Study of the Effects of Different Load Tension Levels on Guided Waves Testing applied to Power Line Cables Sergio Malo, Makis Livadas, Jamil Kanfoud, Tat-Hean Gan, Cristinel Mares	
#184	Signal processing methods to improve the Signal-to-noise ratio (SNR) in ultrasonic non-destructive testing of wind turbine blade Kumar Anubhav Tiwari, Renaldas Raisutis	

Tue	Session 5B 14:00-15:30	Room Berlin
TOPIC: Modelling Chair: Paulo Lobo		
Ref:	Title and Author (s)	
#267	Finite element analysis of fretting contact under various pad geometries Y. M. Korkmaz, D. Çöker	
#37	FE Mesh Generation – Automated Crack Grow Modeling with a View to Stress Intensity Factor Computing Jan Raška	
#47	Development of elevated temperature design evaluation program as per RCC-MRx and its application to sodium test facilities Hyeong-Yeon Lee, Min-Gu Won, Nam-Su Huh, Woo-Gon Kim, Ji-Young Jeong	
#217	Reinforcement Measures to Reduce the Human Induced Vibrations on Stair Steps – A Case Study Pedro Andrade, José Santos	
#218	Application of the Effective Impulse Approach to Stairs Pedro Andrade, José Santos	
#327	Component Standardization Case Study – Kinematic Joints And Interface Development In Mechanical Design Diogo Rechena, V. Infante, L. Sousa	

Tue	Session 5C 14:00-15:30	Room Sidney
TOPIC: Symposium A Chair: A. Fernández-Canteli		
Ref:		
#83	Experimental investigation of short crack growth at notches in 7475-T761 Jürgen Bär, Dominic Tiedemann	
#88	Fatigue damage analysis of the wing-fuselage attachment lug Slobodanka Boljanović, Stevan Maksimović	
#82	Lock-In Thermographic Stress Analysis of notched and unnotched specimen under alternating loads Ralf Urbanek, Jürgen Bär	
#93	Probabilistic definition of the apparent fracture toughness of notched elements based on the TCD M. Muniz-Calvente, S. Blasón, J.A.F.O. Correia, S. Cicero, A.M.P. De Jesus, A. Fernández-Canteli	
#106	Optimal notched specimen parameters for accurate fatigue critical distance determination C. Santus, D. Taylor, M. Benedetti	

Tue	Session 5D 14:00-15:30	Room Paris
TOPIC: Characterization/testing Chair: Paulo Tavares		
Ref:		
#23	An Engineering Predictive Approach of Kitagawa-Takahashi Diagrams of defective A356-T6 alloy considering SDAS dispersion Amal Ben Ahmed, Anouar Nasr, Ahmed Bahloul, Raouf Fathallah	
#46	Nano-mechanical testing of brittle materials Ján Dusza	
#58	Wear damage of TiTaCN-Co cermets at room and elevated temperatures Pavol Hvizdoš ,Ján Balko, Martin Fides, Ernesto Chicardi	
#63	Acoustic emission crack monitoring in rail track based on synchrosqueezed wavelet transform and Tsallis entropy Dan Li, Kevin Sze Chiang Kuang, Chan Ghee Koh, Dong Yang, Wei Xin Ren	
#74	Microstructure and mechanical properties of iron produced at different temperatures via Impact Sintering method B. Romelczyk, A. Laptiev, O. Tolochyn, T. Brynk, Z. Pakiela	
#235	Measurement of Dynamic Fracture in Hot Forming Processing: Effect of Steel and Temperature Abdelouahid El Amri, Mounir El Yakhloufi haddou, Abdellatif Khamlichi	

Tue	Session 5E 14:00-15:30	Room Rio de Janeiro
TOPIC: Composites/Wood Chair: Francesco Iacoviello		
Ref:		
#271	Polymer nanocomposites PE/PE-g-MA/EPDM/nanoZnO and TiO2 dynamically crosslinked with sulfur and accelerators L. Alexandrescu, M. Sönmez, M. Georgescu, M. Niţuică, A. Ficai, R. Trusca, D. Gurău	
#66	Fatigue Behavior of Tailored Blank Thermoplastic Composites with Internal Ply-Drops Petr Homola, Martin Kadlec Roman Růžek, Jakub Šedek	
#272	Polyamide/Polypropylene/graphene oxide nanocomposites with functional compatibilizers: Morpho-structural and physico-mechanical caracterization L. Alexandrescu, M. Georgescu, M. Sonmez, M. Nituica, A. Ficai, R. Trusca, L. Tudoroiu	
#323	Mechanical, Physical and Anatomical Properties of Cryptomeria japonica Wood from the Azores Alfredo Ribeiro, José Lousada, M. Silva, José A.F.O. Correia, Abílio M.P. de Jesus	
#319	Non-Destructive Structural Wood Diagnosis of a Medieval Building Patrícia C. Raposo, Michael Andrade, José A.F.O. Correia, Maria E. Salavessa, Cristina Reis, Carlos Oliveira, Abílio de Jesus	

Tue	Session 6A 16:00-17:30	Room Funchal
TOPIC: Symposium G Chair: Viriato Santos		
Ref:	Title and Author (s)	
#306	Influence of shearing amount and vibration amplitude on noise in shearography H. Lopes, J. V. Araújo dos Santos, P. Moreno-García, J. Monteiro	
#234	Processing steady thermographies by topological derivative methods M. Higuera, J.M. Perales, M.L. Rapún, J.M. Vega	
#305	Numerical study on damage identification using shearography with different shearing amounts J. V. Araújo dos Santos, H. Lopes, P. Moreno-García	
#75	Potentiality of SHM and PFA for a new design approach of low weight aircraft structures F. Romano, U. Mercurio	
#210	Structural damage detection of a cantilever beam under varying temperature using a collection of time series measurements Andreas Kyprianou, Andreas Tjirkallis	
#147	Structural Health Monitoring on an Unmanned Aerial Vehicle Wing's Beam Based on Fiber Bragg Gratings and Pattern Recognition Techniques Alejandro Carvajal-Castrillón, Joham Alvarez-Montoya, Juliana Niño-Navia, Leonardo Betancur-Agudelo, Ferney Orlando Amaya-Fernández, Julián Sierra-Pérez	

Tue	Session 6B 16:00-17:30	Room Berlin
TOPIC: NDT/NDI Chair: Luís Borrego		
Ref:	Title and Author (s)	
#43	Optimizing of MAT method for local wall thinning problems G. Vértesy, B. Bálint, Sz. Gyimóthy, A. Gasparics	
#95	Detection of back-surface crack based on temperature gap measurement Yui Izumi, Koki Uenishi, Yoshiaki Mizokami, Akira Moriyama, Takahide Sakagami	
#102	Fatigue Behavior Evaluation of Additively and Conventionally Produced Materials by Acoustic Emission Method Vendula Kratochvilova, Frantisek Vlasic, Pavel Mazal, David Palousek	
#163	Surface factor assessment in HCF for steels by means of empirical and non destructive techniques Francesca Curà, Raffaella Sesana	
#205	TSA based evaluation of fatigue crack propagation in steel bridge members Takahide Sakagami, Yoshiaki Mizokami, Daiki Shiozawa, Yui Izumi, Akira Moriyama	
#208	Estimation of the dynamic modal parameters of a small-scaled mockup M. Braz-César, J. Ribeiro, H. Lopes	

Tue	Session 6C 16:00-17:30	Room Sidney
TOPIC: Symposium A Chair: Miguel Calvente		
Ref:	Title and Author (s)	
#145	Analytical models of the S-N curve based on the hardness of the material Strzelecki Przemysław, Tomaszewski Tomasz	
#151	Fracture toughness of fibre-reinforced concrete determined by means of numerical analysis Bernardi, P., Michelini, E., Sirico A., Vantadori, S.	
#153	A new strain energy gradient-based model for LCF life prediction of turbine discs Shun-Peng Zhu, Yunhan Liu, Qiang Liu, Hong-Zhong Huang	
#158	Investigations on crack propagation in wheelset axles under rotating bending and mixed mode loading Manuela Sander, Paul Köster, Robert Hannemann	
#146	Estimation of the impact stress gradient in the range of size effect Strzelecki Przemysław, Tomaszewski Tomasz	

Tue	Session 6D 16:00-17:30	Room Paris
TOPIC: Modelling Chair: Antonio Meizoso		
Ref:	Title and Author (s)	
#4	Numerical analysis of bird strike resistance of helicopter searchlight Sebastian Heimbs, Ulrich Fischer, Willy Theiler, Frederik Steenbergen	
#28	Finite Element Analysis of Crack Initiation and Crack Growth for Structural Health Monitoring of Mooring Chains Ángela Angulo, Slim Soua, Tat-Hean Gan, Cristinel Mares	
#41	On strength analysis of highly porous materials within the framework of the micropolar elasticity Victor A. Eremeyev, Andrzej Skrzat, Feliks Stachowicz, Anastasia Vinakurava	
#207	Numerical Analyses of Corroded Bolted Connections Paolo Zampieri, Andrea Curtarello, Emanuele Maiorana, Carlo Pellegrino	
#179	New Method of Numerical Homogenization of Functionally Graded Materials Danuta Miedzińska	
#125	Mitigation of Weld Residual Deformations by Weld Sequence Optimization: Limitations and Enhancements of Surrogate Models Etienne Bonnaud	

Tue	Session 6E 16:00-17:30	Room Rio de Janeiro
TOPIC: Civil Eng, Concrete Chair: Virginia Infante		
Ref:	Title and Author (s)	
#17	Evaluation of damage in concrete from structures affected by internal swelling reactions – A case study João Custódio, António Bettencourt Ribeiro, Carlos Pimentel	
#91	Influence of the SMA constitutive model on the response of structures Pedro Nunes, Paulo Silva Lobo	
#18	Internal swelling reactions in concrete structures – a review on current understanding of the phenomena and prevention methodologies João Custódio, António Bettencourt Ribeiro	
#114	Shape Memory Alloy Based Dampers for Earthquake Response Mitigation J. Morais, P. Gil de Morais, C. Santos, A. Campos Costa, P. Candeias	
#8	Reliability analysis of mattress Reno channel Hocine Hammoum, Karima Bouzelha, Lyes Imerzoukene Meziane Ouharoun	
#12	Reliability analysis of stability to sliding of earthen embankment under seismic effect Karima Bouzelha, Hocine Hammoum, Celia Amirouche, Tassadit Chaouadi	

Wednesday, 6 September 2017

WED, 09:30 - 10:05	PLENARY LECTURE V	Room Funchal
Early crack detection by IRT **Antonio Meizoso** (University of Navarra, Tecnun, Ceit-IK4, Spain) Chair: John Hutchinson (Harvard University, United States)		

WED, 10:05 - 10:40	PLENARY LECTURE VI	Room Funchal
A unified proposal for probabilistic data assessment of fracture and fatigue models **A. Fernández-Canteli** (Univesity of Oviedo, Spain) Chair: Antonio Meizoso (University of Navarra, Tecnun, Ceit-IK4, Spain)		

Wed	Session 7A 11:10-12:40	Room Funchal
TOPIC: Symposium H Chair: José Correia & Miguel Calvente		
Ref:	Title and Author (s)	
#121	Structural integrity and life assessment of a wind loaded cylindrical steel shell structure Dorin Radu, Aleksandar Sedmak, Radu Băncilă	
#175	A probabilistic approach of a non-linear accumulation fatigue model for stress- and strain-life prediction at variable amplitude loading J.A.F.O. Correia, P. Huffman, A.M.P. de Jesus, R.A.B. Calçada, A.A. Fernandes, P. Moreira, A. Fernández-Canteli, Tim H. Topper	
#178	A probabilistic non-linear Miner rule S. Blasón, J.A.F.O. Correia, M. Muniz-Calvente, A.M.P. De Jesus, G. Lesiuk, A. Fernández-Canteli	
#290	Experimental fatigue tests of resin-injected and standard single bolted connections combining S355 mild steel and old material from Eiffel Bridge B. Pedrosa, J.A.F.O. Correia, C. Rebelo, A.M.P. de Jesus, Luís Simões da Silva	
#246	Risk based planning of assessment actions for fatigue life prediction John Leander, Daniel Honfi, Ívar Björnsson	
#293	Fatigue crack propagation analysis of bridge details by parallel computation of modal stress intensity factors Guilherme Alencar, C. Silva Horas, J. G. S. da Silva, A.M.P. de Jesus, Rui Calçada	

Wed	Session 7B 11:10-12:40	Room Berlin
TOPIC: Modelling Chair: John Hutchinson		
Ref:	Title and Author (s)	
#304	Estimation of microstructural failure probability based on restoration of the field distributions laws in components of heterogenous media Mikhail Tashkinov, Elena Spaskova	
#53	Modeling of barium titanate microstructure based on both the boundary element method and homogenization technique Mojtaba Biglar, Feliks Stachowicz, Tomasz Trzepiecinski, Magdalena Gromada	
#99	Elasto-plastic TCD as a method of failure prediction Terekhina Alena, Plekhov Oleg, Susmel Luca	
#122	A numerical analysis of the plastic wake influence on plasticity induced crack closure D. Camas, F.V. Antunes, P. Lopez-Crespo, A. Gonzalez-Herrera	
#212	Hyperelastic material models of polymers of automotive LED lamp construction used for robust fatigue analysis C Okeke, A N Thite, J Durodola M Greenrod	
#170	An Optimized RBF Analysis of an Isotropic Mindlin Plate in Bending Behzad V. Farahani, Jose Berardo, Jorge Belinha, A. J. M. Ferreira, Paulo J. Tavares, Pedro Moreira	

Wed	Session 7C 11:10-12:40	Room Sidney
TOPIC: Symposium A Chair: Sabrina Vantadori		
Ref:	Title and Author (s)	
#240	Fatigue behavior and material characterization of butt welded joints in a high strength steel (class 700 MPa) J. Marques, R. Baptista, V. Infante	
#198	Approximation of the crack driving force for cracks at notches under static and cyclic loading M. Madia, D. Tchoffo Ngoula, U. Zerbst, H. Th. Beier	
#248	A Generalization of Neuber's Rule for Numerical Applications Daniel Kujawski, Joshua LK Teo	
#118	The methodology of transformation of the nominal loading process into a root of notch Chmelko Vladimir, Margetin Matúš	
#252	DIC Study of Cycle-Sequence Sensitivity of Fatigue Crack Closure A. Eremin, S. Panin, A. Byakov, R. Sunder, F. Berto	
#195	Influence of long-term operation on structure, fatigue durability and impact toughness of 09Mn2Si pipe steel S.V. Panin, P.O. Marushchak, I.V. Vlasov, A.S. Syromyatnikova, A.V. Eremin, A.V. Byakov, F. Berto, R. Stankevich, A.M. Bolshakov	

Wed	Session 7D 11:10-12:40	Room Paris
TOPIC: Civil Eng, Concrete Chair: Paulo Lobo		
Ref:	Title and Author (s)	
#32	Low durability of concrete elements due to steel corrosion – cases wherein the reinforcement acted as an internal clock bomb Lino Maia, Farhad Aslani	
#89	Investigation of Aggregate Size Effects on the Compressive Behaviour of Concrete by Electromechanical and Mechanical Impedance Spectroscopy Baris Arslan, Tuncay Kamas	
#34	Mechanical performance of a reinforced concrete beam subjected to an internal confinement in four-point bending Y. Bouamra, K. Ait tahar	
#33	Developing a commercial Self-Compacting Concrete with basaltic aggregate materials Lino Maia, Diana Neves	
#90	Simplified assessment of the effects of columns shortening on the response of tall concrete buildings Ruben Correia, Paulo Silva Lobo	
#35	Behavior of damaged concrete cylinders passively confined B. Moussaoui, K. Ait tahar, Y. Bouamra	

Wed	Session 7E 11:10-12:40	Room Rio de Janeiro
TOPIC: Symposium B Chair: Grzegorz Lesiuk		
Ref:	Title and Author (s)	
#105	Mixed mode I/II/III fatigue crack growth in S355 steel D. Rozumek, Z. Marciniak, G. Lesiuk, J.A.F.O. Correia	
#113	Energy description of fatigue crack growth process - theoretical and experimental approach G. Lesiuk, M. Szata, D. Rozumek, Z. Marciniak, J.A.F.O. Correia, AMP. de Jesus	
#142	Improvement of the fatigue crack growth resistance in long term operated steel strengthened with CFRP patches G. Lesiuk, M. Katkowski, A. Królicka, J.A.F.O. Correia, A.M.P. de Jesus	
#171	A Fracture Mechanics Study of a Compact Tension Specimen: Digital Image Correlation, Finite Element and Meshless Methods Behzad V. Farahani, Paulo J. Tavares, Jorge Belinha, P. M. G. P. Moreira	
#280	Fatigue lifetime improvement and possible fatigue crack growth retardation effect in AISI 304 stainless steel due to high-density electropulsing G. Lesiuk, Z. Zimniak, W. Wiśniewski, J.A.F.O. Correia	
#247	Numerical study of fatigue cracks propagation in butt welded joints in a high strength steel (class 700 MPa) T. Santos, R. Baptista, V. Infante	

Wed	Session 8A 14:00-15:30	Room Funchal
TOPIC: Symposium K Chair: Jesus Toribio		
Ref:	Title and Author (s)	
#166	Estimation of thickness scale in water pipe by artificial neural networks and thermographic model A. Saifi, A. Elamiri, H.halloua, A. Elhassnaoui, S. Sahnoun, Y.Errami, A.Obbadi	
#176	Evaluation of Strength and Fracture Toughness of Ferritic High Strength Steels Under Hydrogen Environments B. Peral, A. Zafra, C. Rodríguez, J. Belzunce	
#308	Crack growth rate curves of hydrogen embrittled steels. Fatigue frequency and concentration influence S. Blasón, C.Rodríguez, F.J.Belzunce, A. Fernández-Canteli	
#149	Hydrogen Induced Damage in Heavily Cold-Drawn Wires of Lean Duplex Stainless Steel M. Iordachescu, M. de Abreu, A. Valiente	
#322	Hydrogen Effects on Progressively Cold-Drawn Pearlitic Steels: Between Donatello and Michelangelo Jesús Toribio	
#321	Stress Corrosion Cracking of Progressively Cold-Drawn Pearlitic Steels: From Tintoretto to Picasso Jesús Toribio	

Wed	Session 8B 14:00-15:30	Room Berlin
TOPIC: Symposium E Chair: José Correia & Carlos Rebelo		
Ref:	Title and Author (s)	
#294	Development of an efficient approach for fatigue analysis of bridge critical details using modal superposition of stress intensity factors C. Silva Horas, Guilherme Alencar, A.M.P. de Jesus, Rui Calçada	
#60	The rehabilitation of three centenarian steel bridges Tiago Mendonça, Mafalda Monteiro, Vítor Brito	
#140	Weldability of old mild steels in maintenance of historical steel structures Lars Sieber, Andrè Kilian, Holger Flederer, Gunther Göbel, Marco Steinhauser	
#40	Tagus river centenarian steel bridges' rehabilitation Tiago Mendonça, Mafalda Monteiro, Vítor Brito	
#141	The brittle fracture behaviour of old mild steels Lars Sieber, Richard Stroetmann	
#167	Assessment of fatigue limits in historical welded railway bridges in Poland Wichtowski B., Hołowaty J.	

Wed	Session 8C 14:00-15:30	Room Sidney
TOPIC: Characterization/testing Chair: Ricardo Claudio		
Ref:	Title and Author (s)	
#49	Proposal of a stress-based isothermal LCF life model for Aluminium alloy cylinder heads Cristiana Delprete, Raffaella Sesana	
#55	Material Influence on Crenellation Effectiveness in Damage Tolerant Design Jin Lu, Volker Ventzke, Norbert Huber Nikolai Kashaev	
#194	Uncertainties of the Critical Buckling Pressure of a Tube Hyung-Kyu Kim	
#243	Comparison of the fatigue behaviour of AA6082-T6 and AA6061-T651 aluminium alloys L.P. Borrego, J.D. Costa, J.A.M. Ferreira	
#262	Corrosion effects on mechanical properties of sintered stainless steels C. Barile, C. Casavola, C. Pappalettere	
#244	Plasticity induced closure under variable amplitude loading in AlMgSi aluminium alloys L.P. Borrego, J.D. Costa, J.A.M. Ferreira	

Wed	Session 8D 14:15-16:00	Room Paris
TOPIC: Civil, Monitoring Chair: Paulo Tavares		
Ref:	Title and Author (s)	
#260	Deformation monitoring of load-bearing reinforced concrete beams R.Tsvetkov, I.Shardakov, A.Shestakov, G.Gusev, V.Epin	
#278	Intellectual monitoring of artificial ground freezing in the fluid-saturated rock mass Panteleev I., Kostina A., Zhelnin M., Plekhov A., Levin L.	
#222	Dynamic Assessment of the São João Bridge Structural Integrity Xu Min, Luís Oliveira Santos	
#215	Dynamic Tests for Assessment of Pedestrian Comfort and Fatigue Life Estimations for Design of a Stayed Highway Bridge A.M. Prato, F. Pinto, M.A. Ceballos, C.F. Gerbaudo, C.A. Prato	
#253	Crack control in concrete using shock wave techniques I.Shardakov, A.Bykov, A.Shestakov, I.Glot	
#128	Analysis of the environmental degradation effects on the cables of "La Arena" bridge (Spain) J.A. Álvarez, R. Lacalle, B. Arroyo, C. Alonso	

Wed	Session 8E 14:00-15:30	Room Rio de Janeiro
TOPIC: Wood/Bio Chair: Virginia Infante		
Ref:	Title and Author (s)	
#239	Mechanical properties of Wood Construction Materials from a Building from the 19th Century Patrícia Raposo, José A.F.O. Correia, Dinis Sousa, Maria E. Salavessa, Cristina Reis, Carlos Oliveira, Abílio M.P. de Jesus	
#313	Currently used systems of dental posts for endodontic treatment Joana Machado, Paulo Almeida, Sampaio Fernandes, Arcelina Marques, Mário Vaz	
#57	Longitudinal bonded joints of timber beams using plywood and LVL plates Lokaj Antonín, Vavrušová Kristýna	
#318	Numerical Modelling of a Wood Pavement of a 13th Century Building Patrícia C. Raposo, Michael Andrade, José A.F.O. Correia, Maria E. Salavessa, Cristina Reis, Carlos Oliveira, Abílio de Jesus	
#316	Bone Immobilization devices and consolidation mechanisms: Impact on healing time Andreia Flores, Arcelina Marques, Joana Machado, Miguel Marta, Mário Vaz	

Wed	Session 9A 16:00-17:30	Room Funchal	Wed	Session 9B 16:00-17:30	Room Berlin	Wed	Session 9C 16:00-17:30	Room Sidney	Wed	Session 9D 16:00-17:30	Room Paris	Wed	Session 9E 16:00-17:30	
TOPIC: FCG Chair: Luís Borrego			TOPIC: Symposium E Chair: José Correia & John Leander			TOPIC: SHM and Structural Integrity Chair: Mário Vaz			TOPIC: Fracture Analysis Chair: Luís Reis			**NO SESSION**		
Ref:	Title and Author (s)		Ref:	Title and Author (s)		Ref:	Title and Author (s)		Ref:	Title and Author (s)				
#30	Weak and strong bi-material interfaces and their influence on propagating cracks in plane elastic structures Johannes Scheel, Andreas Ricoeur		#168	Toughness tests on steels from old railway bridges Hołowaty J.		#20	Fatigue analysis of notched specimens made of direct-quenched ultra-high-strength steel under constant amplitude loading Mohammad Dabiri, Timo Björk		#42	Failure investigation of the crankshaft of diesel engine Lucjan Witek, Feliks Stachowicz, Arkadiusz Załęski				
#54	Formulation of CTOD design curve considering the yield to tensile ratio Yoichi Kayamori, Tomoya Kawabata, Yukito Hagihara		#223	The impact of the corrosion on the structural behavior of the truss railway bridge Pavel Ryjáček		#48	Torsion vibrations monitoring of turbine shafts Jaroslav Václavík, Jan Chvojan		#98	A non-local damage model for brittle fracture in metallic structures with stress concentrators Anastasiia Kostina, Oleg Plekhov, Luca Susmel				
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Wednesday, 17:30 – 18:00	CLOSING SESSION	Room Funchal
Conference Organizing Committee		

Abstracts

Editorial

2nd International Conference on Structural Integrity, ICSI 2017,

hosting The 2nd Multi-Lateral Workshop on Fracture and Structural Integrity related Issues

4-7 September 2017, Funchal, Madeira, Portugal

Editorial

Pedro Moreira, Paulo J. Tavares

INEGI / Faculty of Engineering Porto University, Portugal

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 ICSI2017 include, but are not limited to Fracture and Fatigue, Stress Analysis, Damage Tolerance, Durability; Crack Closure, Nanoscale Damage, Material Ageing, Coatings Technology, Environmental Effects, Joining Technologies; Image processing for SHM, New materials, Structural Integrity in Biomechanics and many other exciting research topics.

In 2017, ICSI is proud to host the Second Multi-Lateral Workshop on Fracture and Structural Integrity, jointly organized by the Portuguese, Spanish and Italian groups on fracture. The Portuguese Structural Integrity Society and the Italian, and Spanish Groups of Fracture are strenuous scientific associations involved in several activities, under the umbrella of both the European Structural Integrity Society and the International Congress on Fracture. The second multilateral workshop is expected to increase the level of cooperation amongst these groups and increase the awareness to the research work done in the Iberian-Latin region of Europe on fracture and structural integrity related issues.

This year, the ICSI organizers 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. ICSI2017 therefore launched a number of invitations to prominent researchers all over the globe to lecture on their own research fields, such as Prof. Alfonso Fernández-Canteli, Prof. Antonio Martín-Meizoso, Prof. Francesco Iacoviello, Prof. John W. Hutchinson, Prof. Pedro Camanho, and Prof. Manuel Freitas. ICSI2017 also started the organization of dedicated symposia and hosted the organization of ESIS Technical Committees annual meetings. Apart from the publication of the proceedings in Procedia Structural Integrity and a special issue in the International Journal of Fatigue, special issues on six other highly relevant journals in the field of Structural Integrity further supported the conference: Engineering Failure Analysis; Fatigue and Fracture of Engineering Materials and Structures; Journal of Strain Analysis for Engineering Design; Journal of Strain Analysis for Engineering Design; Bridge Structures, and; International Journal of Conservation Science.

The response to these efforts has been overwhelming: Twelve symposia were proposed and accepted for organization; two ESIS Technical Committees annual meetings were hosted: TC10 on Environmentally Assisted Cracking and TC12 on Risk Analysis and Safety of Large Structures and Components; the number of abstract submissions nearly doubled from 2015: over 250 abstracts were approved for oral communication and nearly 200 full papers have been accepted for the conference proceedings.

The biennial ICSI conferences, at the end of summer and resident in Funchal, the capital of the wonderful Madeira Island, 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 2019.

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.

Duplex stainless steels fatigue crack propagation resistance

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ABSTRACT

Austeno-ferritic (duplex) Stainless Steels are prone to age hardening and to embrittle over a wide temperature range depending on their chemical composition and on, obviously, the heat treatment conditions. This is mainly due to precipitation phenomena that occur inside ferritic grains and at ferrite-austenite grain boundaries with a kinetic that is influenced by the steel chemical composition and by the temperature. The aim of this work is to offer a complete view of the influence of the chemical composition on the DSSs fatigue crack propagation, considering different ageing temperatures and different loading conditions. According to the experimental results, the following conclusions can be summarised:

- In annealed conditions, 2101 is characterized by the lowest fatigue crack propagation resistance, meanwhile 2205 and 2507 are characterized by an analogous behaviour;
- After a tempering at 475°C for 1000h, the reduced susceptibility of the 2101 DSS to embrittle (longest incubation time slower precipitation kinetics) implies a reduced decrease of the fatigue crack propagation. The three investigated DSSs are characterized by an analogous fatigue crack propagation resistance. Considering the fatigue crack propagation micromechanisms, the 475°C embrittlement implies an increase of the importance of cleavage.
- After tempering at 800°C, 2101 DSS is characterized by a ferritization and an increase of the grains dimensions. As a consequence, an increase of the threshold values K_{th} is observed. Instead, 2205 and 2507 are characterized by the precipitation of secondary phases, carbides and nitrides with a different kinetic. 2507 DSS, characterized by the lowest incubation time for the precipitation processes, shows the worst behaviour, with a decrease of the threshold values K_{th}, an increase of the crack growth raates for all the investigated K values, with and increase of the importance of phenomena like cleavage and the initiation and propagation of intergranular and transgranular secondary cracks.

Early crack detection by IRT

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Abstract Infrared thermography (IRT) has been used for detection of small trench defects introduced by Focused Ion Beam (FIB) in a nickel-based superalloy. Because of the high electrical resistivity of nickel alloys (in comparison with, for example, steels) and their small thermal conductivity, these alloys are particularly well suited for detection of thermal gradients produced at tips of cracks in combination with direct current heating. An experimental program has been conducted, at different initial temperatures, with loaded and unloaded samples under stationary and thermal transient conditions. Under stationary thermal conditions, it is concluded that this technique is able to detect notches of 100 micrometers up to 500 ºC.

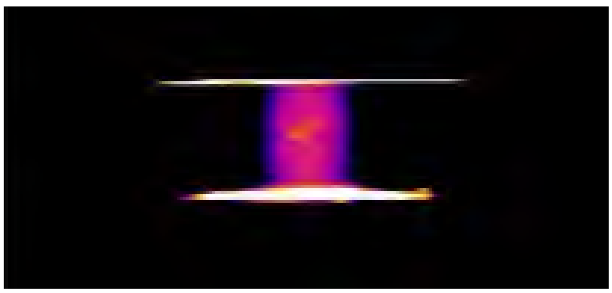

Figure 1 – *Infrared thermograph after a direct current pulse showing two artificially introduced crack-like defects.*

A unified proposal for probabilistic data assessment of fracture and fatigue models

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Abstract A unified probabilistic modelling for static and fatigue failure prediction is, or should be, a major concern for material scientists and practicing engineers as an indispensable basis for design with accomplishment of structural integrity. Phenomenological models may be suitable candidates for achieving this aim when certain probabilistic requirements are fulfilled. An overview about such fatigue models, based on compatibility, is presented. It includes the basic probabilistic Weibull model for fatigue assessment, some of its extensions or improvements, and the crack growth rate model. Usually, the experimental programme is carried out according to the test strategy dictated by the model, the assessment and interpretation of the experimental results being the key point. In fact, a model providing a "faultless data assessment", represented by the experimental failure distribution, is insufficient for ensuring transferability from lab results to practical design of components unless a methodology encompassing probabilistic definition of the assessed data and conversion of the experimental results distribution into a primary failure cumulative distribution is achieved.
In this presentation, a methodology denoted generalized local approach (GLA) is applied to static and fatigue failure cases allowing the primary failure cumulative distribution function (PFCDF) to be derived from the experimental failure cumulative distribution function (EFCDF). The PFCDF can be considered a "relative material property" with some limitations (particularly in the fatigue case) allowing an objective characterization of the material to be achieved, and therefore transferability from the laboratory characterization ensured. The GLA requires validity of the weakest link principle and the adequate choice of the generalized parameter, which incidentally can be checked by applying recursively model simulation. Under such conditions, the model may be used for suitably prediction of both brittle and ductile static failures, whereas its extension to fatigue requires the probabilistic definition of the S-N field and its normalization in order to allow the whole S-N field to be reduced as a simple cumulative distribution function.

Key Words: Phenomenological models based on compatibility, generalized local model, experimental and primary failure distribution, generalized parameter.

#1 Ultimate Strength Capacity of Welded Joints in High Strength Steels

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Abstract High strength steels are nowadays used in a wide range of weight lifting applications, e.g. spreaders and cranes, where there is a demand on lightweight design of these structures with increased structural performance where the welds become more sensitive to failure. This study focuses on investigating the influence of the mismatch in the yield strength of the filler material and the welds penetration depth on the ultimate strength capacity and failure modes of butt and fillet welded high strength steels in the grade range of 350 – 960 MPa. The load carrying capacities of these mentioned joints are evaluated with experiments and compared with the estimations by finite element analysis (FEA), and design rules in Eurocode3 and American Welding Society Code AWS D1.1. Fully penetrated joint with under-matched filler material is more ductile and the ultimate strength capacity of base plate can be achieved. It is observed that joints with under-matched filler material are more sensitive to penetration ratio. This influence is more pronounced in joints in S960 steel welded with under-matched filler material. It is also found that the design rules in Eurocode3 (valid for design of welded joints in steels of grade up to S700) can be extended to designing of welds in S960 steels by the use of correlation factor of one.

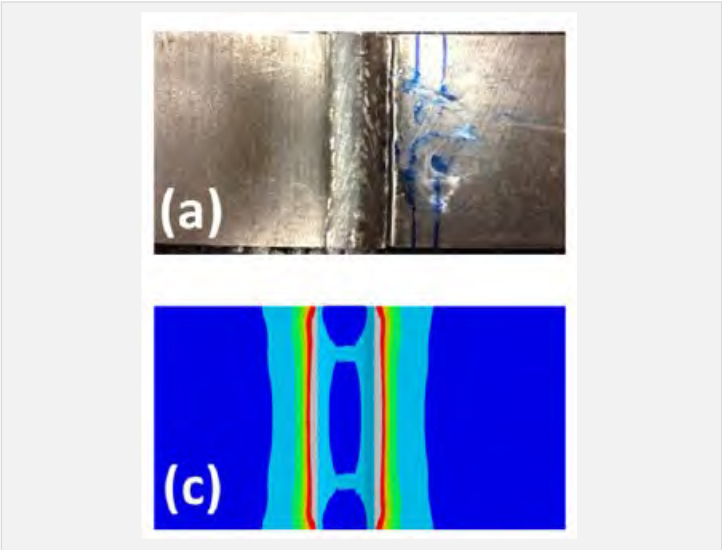

Figure 1 – *Estimated failure location, experimental and FEA.*

#3 Life Extension of Welded Structures Using HFMI Techniques - Potential Application to Offshore Structures

Fikri Bashar Yalchiner[1], Zuheir Barsoum[2]

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Abstract Fatigue damage development in welded structures is a local phenomenon and if one need to achieve an extension of the life for the structure local post weld improvements need to be use in order to reduce/remove local features which contribute to the fatigue damage. In order to enhance the life time of load carrying welded structures without large amount of cost investments, e.g. redesign and replacement of existing structures, post weld improvement techniques need to be more applied. New High Frequency Mechanical Impact (HFMI) technologies have been developed in the last 10 years which enables cost-effective life extension and reparation of welded structures. The use improvement techniques for technical life enhancement upgrade and repair of welded structures within various industries, e.g. oil and gas, have been an accepted practice. HFMI treatment techniques are based on localized peening process of the welded joints and the devices are portable. The impacting results in a local cold plastic deformation which remove weld defects reduce stress concentration and induce compressive residual stresses which eventually will enhance the fatigue life of the welded structure. An overview of existing improvement techniques for welded structures is given followed by description of new technologies (HFMI). A brief description of the new international guideline and design recommendations within the International Institute of Welding (IIW) is given. Several validation studies on the fatigue performance of HFMI techniques are presented and onsite potential applications of the techniques for joints in fixed offshore structures are outlined.

#4 Numerical analysis of bird strike resistance of helicopter searchlight

Sebastian Heimbs[1], Ulrich Fischer[2], Willy Theiler[2], Frederik Steenbergen[2]

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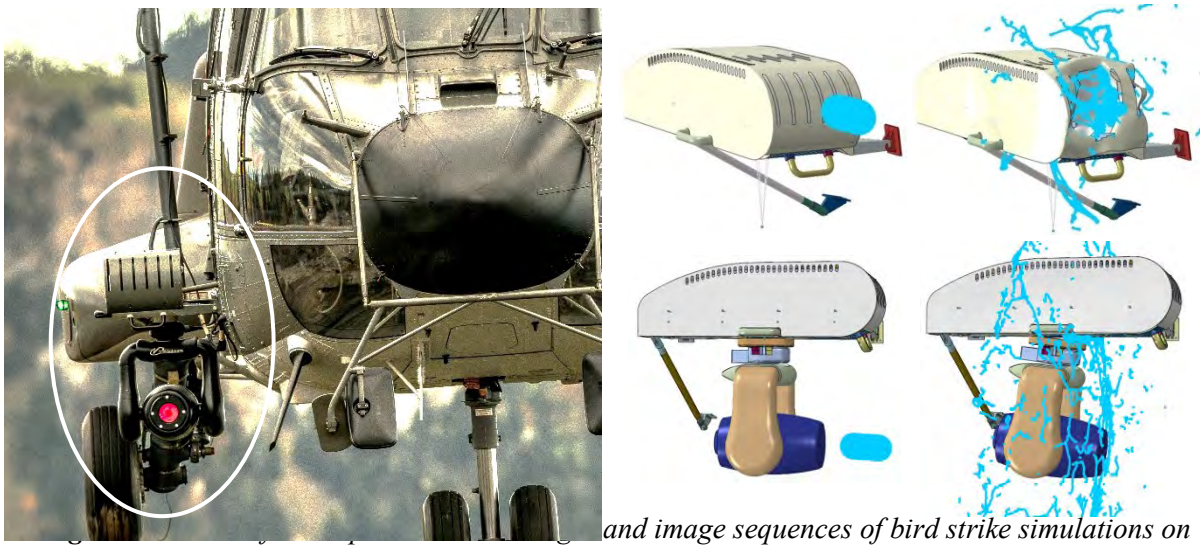
[2]RUAG Aviation, 6032 Emmen, Switzerland

Abstract Bird strike is a major threat to aircraft structures, as a collision with a bird during flight can lead to serious structural damage. For helicopters the windshield, forward airframe structure, rotor blades and all exterior equipment parts are exposed to the risk of bird impact. Consequently, aviation authorities require that such structures need to prove bird strike resistance before they are allowed for operational use, which primarily had to be demonstrated in full-scale bird impact tests in the past. Today, as numerical simulation techniques have evolved and proven accuracy, compliance can more and more be shown by sufficiently validated numerical analyses. This study shows such an example of successful simulative demonstration of bird strike resistance of a searchlight and its pod as external equipment of a military helicopter. The finite element model was built up and validated step by step according to the building block approach from coupon level up to the full-scale structural level. The focus was on the accurate non-linear constitutive modelling of the different aluminum alloys and mechanical fasteners of the target structure. The searchlight pod as well as its internal electrical components and attachments were modelled with a high level of detail in order to allow for accurate results evaluations. A validated smoothed particle hydrodynamics (SPH) bird impactor model was used to simulate different load cases and impact positions of this fluid-structure interaction scenario with a water-like soft body projectile. Although plastic deformations and partial fracture of the outer housings of the structure were observed, no critical failure mode, detachment of critical parts or loss of structural integrity occurred (Fig. 1). These analyses were accepted by the authorities as means of compliance and demonstrate today's progress in airworthiness certification by simulation.



and image sequences of bird strike simulations on pod (top) and searchlight (bottom) (photo copyright & permisson: VBS)

#7 Fracture mechanics based estimation of fatigue lives of laser welded joints

Rakesh Goyal[1], Sergey Bogdanov[2], El-zein Mohamad[1] and Gregory Glinka[2]

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Abstract The need for lightweight structural parts is increasing than ever mainly due to emission control regulations and fuel efficiency requirements. The use of high strength steel materials along with thinner gauge sections can be significantly helpful to achieve towards this objective. It is well known that joints are integral to any structural parts. The conventional joining methods like resistance spot welding and arc welding have several challenges during welding of thin sheet high strength steel materials. The laser welding process has emerged as one of the better joining process which can help resolve some of these challenges. Due to lower heat input from the laser welding process, it results into smaller size weld heat affected zone and lower overall distortion of the structure. The laser welding process presents an exciting opportunity to the design engineers for the lighter weight structural design. However, currently there is a major gap in terms of understanding the fatigue performance of the laser weld joints. In order to understand the fatigue behavior of laser weld joints, detailed experimental and numerical investigation has been carried out during this work. An extensive amount of experimental fatigue test data has been generated for laser welded joints produced using three grades of high strength steel materials (HSLA and UHSS grades) for several thicknesses (1mm, 1.6mm, 2mm and 3mm). The fatigue test data was obtained at two different R-ratios (R=0.1 and R=0.3). Further, the studies included the effect of laser weld orientation with respect to applied loading direction. Detailed metallurgical investigations have been carried out to understand the crack growth behavior in laser weld joints. Strain life based fatigue analysis method which has been successfully applied to study weld toe failures for the arc weld joints is not sufficient for the laser weld joint. Laser weld joints have unique challenges due to weld root crack failures and extremely high stress concentration at the location of crack initiation. The fracture mechanics based method for fatigue life assessment of laser weld joints has been developed based on the detailed three dimensional finite element stress analysis, see Fig. 1. Numerical studies show good correlation of the estimated fatigue lives obtained using proposed fracture mechanics method with the experimentally data.

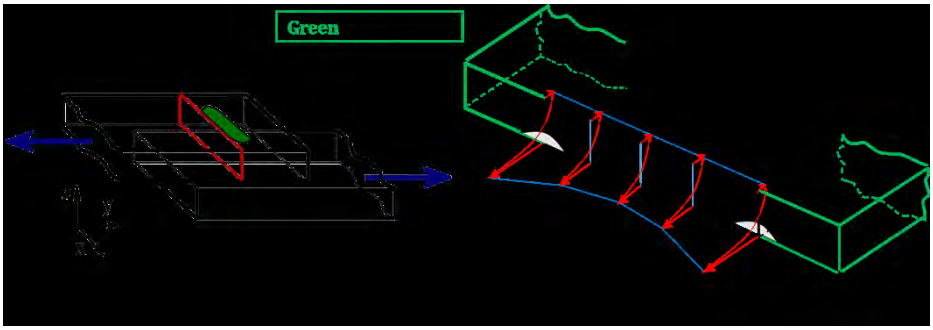

Figure 1 – Schematic of the detailed stress analysis of a typical laser weld

Key Words: Laser welds, Stress analysis, Fracture Mechanics, High Strength steels

#8 Reliability analysis of mattress Reno channel

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Abstract The term canal is usually understood to mean an open artificial channel that permits the free flow of water. Canals are used for irrigation, drainage and water supply. The free surface flows in these channels are in contact with its walls which become a characteristic of the flow as well as its geometry. A revetment is often used for canals, such as flexible structures, they have the function of providing the natural soil with mechanical protection against erosion. Among the most widely used flexible structures around the world, and with great success for transport of water in open channels, we have Reno mattress revetments.

Traditionally, their design is based on deterministic analysis. Safety factors recommended by the design codes are applied to take account of these uncertainties and ensure a sufficiently safe design. However, this approach does not make it possible to evaluate the risks associated with the failure of the flexible revetment structure and therefore its reliability. During the design of the Reno mattress revetment, civil engineers measure and calculate its stability based on a frequential flow rate, in order to optimize the cost of the structure. However, in practice, the evaluation of the frequencial flow is tainted by uncertainties. The change in the flow rate of the water alters the integrity of the structures and must be able to be predicted in order to avoid the accelerated wear of the system by fatigue of the material or even its destruction when the flows exceed a certain limit. It is then easy to understand the importance of establishing reliable models for predicting such behaviors.

Reliability theory based on probabilistic formulation can respond appropriately, however it raises theoretical, numerical and application difficulties since it requires, in particular, the modeling of uncertainties by laws and statistical parameters. The simplest and most general probabilistic theory is that of the Poisson process which applies to any accidental phenomenon (not predictable by deterministic laws) with extreme values such as: rainfall and project flood.

In the present work, we develop a probabilistic approach to analyze the failure functions related to the overall stability of a Reno mattresses canals. The considered state functions are those related to critical velocity, stability of the channel bottom, deformation effects, traction forces and residual velocity at the underside of the revetment. To take the uncertainties into account, the water flow rate is considered as random variable, generated by Poisson law. For the need of reliability analysis, Monte Carlo simulation method is used. Also, the Matlab© software is used for generating random draws. The developed method in this work is applied to a practical example which is taken from the engineering field (see Figure 1).

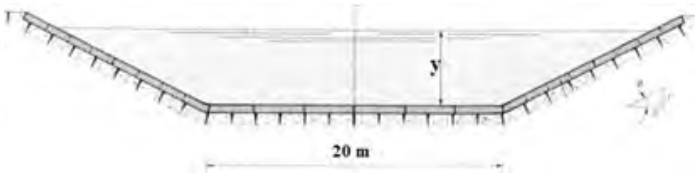

Figure 1 – *Cross section of the mattress Reno channel*

#10 Assessing the intergranular crack initiation probability of a grain boundary distribution by an experimental misalignment study of adjacent slip systems

Florian Schaefer[1], Eric P. W. Lang[1], Michael Bick[2], Alain F. Knorr[1], Michael Marx[1], Christian Motz[1]

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[2]Saar-Hartmetall und Werkzeuge GmbH, Puettlingen, Germany

Abstract Crack initiation at grain boundaries due to blocked slip transfer is a main failure mechanism during the fatigue of metals. A quantification of the resistance effect of a grain boundary is needed to assess a textured or un-textured microstructure. Geometric approaches based on the misalignment of slip systems in adjacent grains are widely-used. Hence, we validated the geometric transmission factor of Shen et al. in coarse-grained high-purity aluminum under the assumption that the combination of a large slip activity and a blocked slip at a grain boundary leads to intergranular crack initiation and revealed that a detailed knowledge of the 3D-orientation of the grain boundary is essential. Thereby we gathered information about the 3D-microstructure using FIB-cross-sectioning. The influence of incompatibility stresses due to elastic anisotropy is assessed by a comparison of the results in quasi-isotropic aluminum to that in coarse-grained high-purity nickel. Hence it is possible and shown how to evaluate potential crack initiation sites for a specific microstructure or to estimate the fatigue strength of a texture in terms of a crack initiation probability.

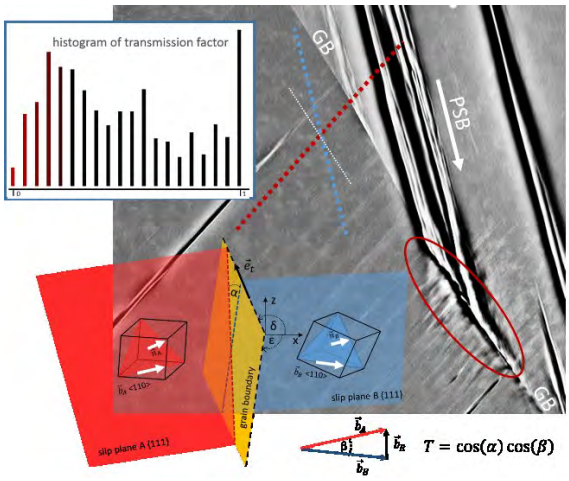

Figure 1 *– persistent slip bands hitting a grain boundary causing intergranular crack initiation in coarse-grained nickel. Slip transfer is blocked due to a strong misalignment of slip systems marked by dotted lines. Inset shows a histogram of quantified resistance values of a grain boundary distribution for a cube texture.*

#12 Reliability analysis of stability to sliding of earthen embankment under seismic effect

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Civil engineering department, University of Mouloud Mammeri, 15000 Tizi Ouzou, Algeria

Abstract Traditionally, the stability to sliding of the embankment slope of a small dam is performed on the basis of deterministic calculations, such as Bishop or Fellenius method. A global safety factor of embankment sliding, based on the average values of calculation parameters, is determined as recommended by dimensioning guides. These coefficients are applied to take account the uncertainties related to models approximations, to hazards on the quantities and the phenomena not taken into account.

Current advances in the quantification of uncertainties, linked to the behavior of embankments, using reliable approaches, allow a better consideration of specific hazards to the various random parameters and a better evaluation of their safety. This theory of reliability aims to evaluate the failure probability of the embankment knowing the criterion of limit state to the slopes sliding and the variability of parameters that intervene in this criterion. The embankment is finally considered safe if this failure probability is less than a reference value, called admissible failure probability.

In this study, we are interested in stability analysis of upstream slope sliding of homogeneous embankment realized with local materials. This embankment is taken among small dams of Tizi Ouzou region (Algeria). The global factor of safety to sliding is obtained by Fellenius method, taking into account seismic effect and saturation line. The failure probability of the embankment to the limit state is evaluated by the classical Monte Carlo method. The considered random variable in this probabilistic analysis is the acceleration coefficient of seismic zone, which is generated by a lognormal distribution.

Finally, in this study a program implemented with the Matlab© software is used to generate random draws. The developed method in this work is applied to a practical example which is taken from the engineering field (See Figure 1).

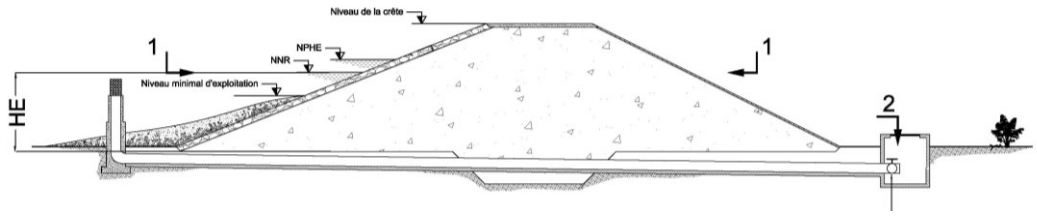

Figure 1 – *Cross section of earthen embankment of the small dam in Tizi Ouzou*

#13 Investigation on the structural damage of a double-hull ships, Part I – Ship collision

Aditya Rio Prabowo[1,*], Seung Jun Baek[2], Dong Myung Bae[2], Joung Hyung Cho[1], Jung Min Sohn[2]

[1]*Interdisciplinary Program of Marine Convergence Design, Pukyong National University, Nam-gu, Yongso-ro 45, Daeyeon-dong, Busan 48513, South Korea.*
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[2]*Department of Naval Architecture and Marine Systems Engineering, Pukyong National University, Nam-gu, Yongso-ro 45, Daeyeon-dong, Busan 48513, South Korea.*

Abstract Marine structure is designed to be able resist various load conditions during its operational period. However, in design process, a detail analysis to assess structural response against accidental loads, such collision and grounding, has not been included for both merchant ship and navy vessel. These loads are spontaneous and several remarkable casualties may possibly occur after collision and grounding take place.

Aim of this paper is to investigate structural damage on the target ship during collision and grounding considering on failure process and damage extent. This work is divided into two parts which in the Part I, ship collision is discussed, and the Part II deals with interaction of ship structure with sea bottom topology in grounding.

In the Part I - Ship Collision, condition of the side structure is observed, including the inner hull after impact which is considered as the key to determine safety condition of ship cargo. A passenger ship is modelled in this work and designated as the *struck ship* which will be struck by the *striking ship* in collision process. Condition of ship cargo on the car deck is estimated based on displacement contour of the inner hull. Resistance capability of the double-hull structure against side collision is evaluated. Virtual experiment is conducted by nonlinear finite element method (FEM) in order to calculate several dynamic collision scenarios which are built based on physical parameter, namely target location and hull material. Based on calculation results, damage on the side hull is found to be highly influenced by height relative between two ships prior collision. Critical location is summarized and result tendency indicates that in the mentioned location, the striking ship produces larger tearing on the lower part of the struck ship. Contribution level of the applied materials on the target ship is summarized in later part in order to evaluate significance of each material in encountering side collision.

#14 Investigation on the structural damage of a double-hull ships, Part II – Grounding impact

Aditya Rio Prabowo[1,*], Hyun Jin Cho[2], Dong Myung Bae[2],

Jung Min Sohn[2], Joung Hyung Cho[1]

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Abstract Possibility of marine and offshore structures to experience accidental load has been seriously considered up to this day. Remarkable casualties on related aspects, for example ship structure, cargo, environmental damage are rising demand to ensure ship safety which this subject is observed in marine structure and impact engineering. Ship is an example of marine structure that has mobility to carry and transport commodities which in same time, it may be subjected to accidental load during its operational. Aim of this paper is to investigate damage extent of the *target ship* under different accidental load, namely collision and grounding with considerations to failure process and deformation contour are evaluated. This work is divided into two parts which in the Part I, ship collision is discussed, and the Part II deals with interaction of ship structure with sea bottom in grounding.
In Part II - Grounding impact, evaluating tearing damage on the bottom structure is essential in estimating environmental casualties caused by oil leakage. A chemical tanker is modelled to be the *target ship* in a series of grounding scenario. Condition of the structural damage and tendency of the internal energy, crushing force and structural acceleration are observed. Prediction of the tearing opening and location of the initial failure in further grounding process are also presented in this paper. Virtual experiment is conducted by nonlinear finite element method in order to calculate the defined grounding scenarios which are built based on the target location on the bottom structure. Based on calculation results, condition of the double-hull structure is found to be highly influenced by arrangement of longitudinal members which is evidenced that this member provides higher resistance than the transverse part during encounters crushing process by the rock in grounding process.

#17 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 bridge 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.

#18 Internal swelling reactions in concrete structures – a review on current understanding of the phenomena and prevention methodologies

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Abstract Alkali–silica reaction (ASR) and delayed ettringite formation (DEF) in concrete are a major durability problem as they result in significant maintenance and reconstruction costs to concrete infrastructures all over the world. During the 1920s and 1930s numbers of concrete structures in California, USA, were observed to develop severe cracking within a few years of their construction. Stanton, in 1940, was able to demonstrate that this cracking was related with the existence of an alkali-aggregate reaction. In Portugal, the first cases were detected in the 1980s (Pracana dam and Alto Ceira dam) and 1990s (Duarte Pacheco viaduct). DEF is relatively "new" with respect to ASR, since it was only detected in the middle of 1980's in pre-stressed concrete railway ties on the eastern coast of the United States. The occurrence of DEF in Portugal is much more recent, with the first case being detected only in 2003, in pre-fabricated concrete railway ties. Despite decades of study, the underlying chemical and physical reaction mechanisms of ASR and DEF remain poorly understood and this has resulted in the inability to efficiently assess the risk, predict the service life, and mitigate deterioration in susceptible structures. Because of that, the problem was not totally eradicated and today numerous concrete structures still exhibit ASR and ISR.

This paper intends to provide a succinct outline of the latest research and developments in the field of ASR and DEF, in respect to reaction mechanisms, factors influencing their development and resulting structural effects. In addition, the latest methodologies, based on state-of-the-art-knowledge, which may be used by construction industry stakeholders in the prevention of ASR and DEF in new concrete structures is presented and discussed. Current information about the synergistic effects of these two reactions is also included in the paper.

Figure 1 – *Example of structures where ASR and DEF are often observed (left and middle) and of the cracking resulting from their development (right)*

#20 Fatigue analysis of notched specimens made of direct-quenched ultra-high-strength steel under constant amplitude loading

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Abstract Notched specimens made of a direct-quenched ultra-high-strength steel were investigated by applying the different methods available for the stress-strain analysis of notched components. The methods included the linear rule, Neuber's rule and the strain energy density method. The latter two methods were used in modified forms to improve their estimation capabilities under plane strain conditions. Meanwhile, an elastic-plastic finite element model equipped with the stabilized cyclic stress-strain curve as the material response was used to capture the strain values at the notch root required for the life estimation. The most advanced method based on the theory of critical distances, abbreviated as TCD, was utilized as well. This method, using the results of the elastic-plastic finite element model, was able to define a material characteristic length, which is a material constant, regardless of the notch configurations or the number of cycles in a low-cycle regime. The results showed that the finite element analysis and TCD method are able to estimate the lives closest to the experimental values. The TCD method also predicted the lives with the lowest level of unnecessary conservatism, especially in the case of specimens with sharper notches.

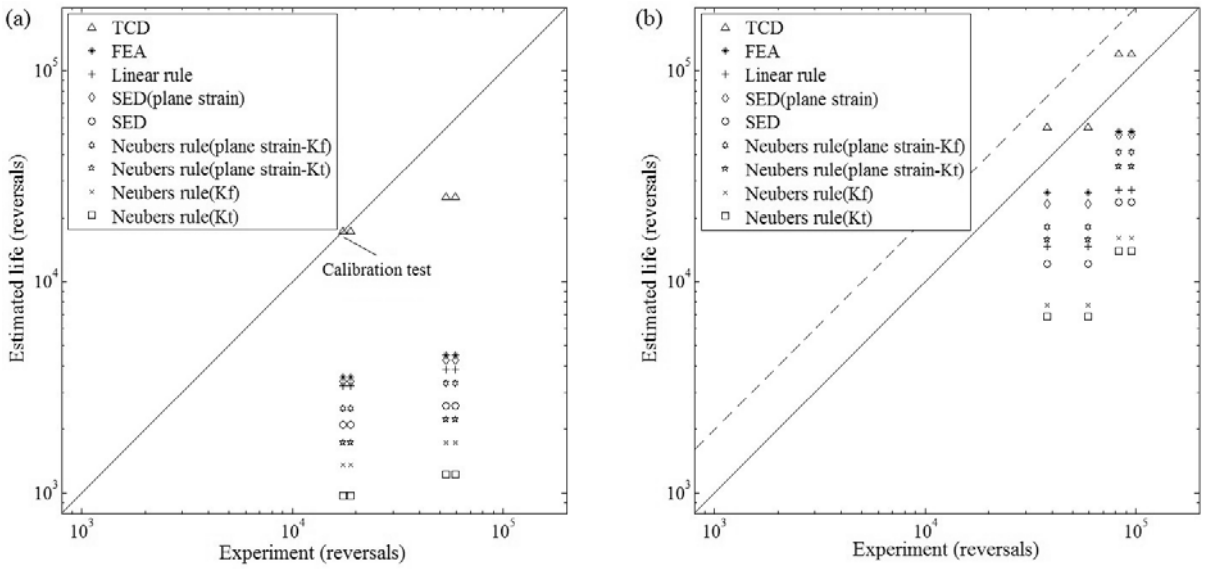

Figure 1 - *Comparison of estimated and experimental lives for notch specimens (a) R = 0.5 mm and (b) R = 1.5 mm*

#21 Effect of fiber length on the mechanical properties of high dosage carbon reinforced composites

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Abstract Short fibers are effective reinforcements in strengthening and toughening polymer materials. It is reported that even small amounts of fibers drastically increased composite strength. However, for high fiber dosage the dispersion and interface adhesion is quite poor reaching to lower stiffness and strngth efficiency. The effects of fiber length on mechanical properties of low content of short fiber reinforced composites is usually associated with a gain with the increasing of fiber length, but for high dosage this statement is not entirely consensual.

This paper intends to contibute for the better understanding of the effect of the fiber length on the mechanical performance of high dosage fiber reinforced composites. Composite plates were manufactured by compression moulding, using short carbon fibers reinforcements (2, 4 and 6 mm in length) with 60% wt fiber fraction and the Biresin®CR120 resin as matrix. The plates after post cure process had about 150x100x5 mm, from which tensile and DMA specimens were machined for desired dimensions. Tensile tests were performed using an electromechanical Instron Universal Testing machine, with a displacement rate of 1 mm/min. Dynamic mechanical analysis (DMA) was performed using a Triton Technology TRITEC 2000 machine and specimens bi-supported inside the thermal chamber ranging the temperature between 20 to 180 oC, in order to obtain the dynamic elastic modulus and viscous modulus. Fracture surfaces were gold sputtered and observed with a scanning electron microscope (Philips XL30) in order to analyse the fiber dispersion and adhesion.

High dosage composites exibits very low efficiency parameters both in stiffness and particularly in tensile strength. Stiffness increases in order of 25% when fiber length increases from 2mm to 4mm, but afterwords decreases for 6mm fiber length composites. The same tendency was observed for the tensile strength meaning that poor fiber dispersion and disorder was achieved for 6mm fiber length. The results of DMA indicate, however, that modulus storage increases still slightly when fiber length increases from 4mm to 6mm.

#22 Probabilistic Fatigue Crack Growth Assessment of Al 7075-T6 Aerospace Component

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Abstract This attempt proposes an engineering probabilistic approach to predict the fatigue crack growth life of 7075-T6 Aluminum alloy used in an aeronautic context (case of attachment lug). The developed approach was implemented by coupling of Extended Finite Element Method (XFEM), Residual Corrected Stress intensity Factor (RC-SIF) and Monte Carlo simulation (MCS). The residual stress distribution near crack tip and the material dispersions are taken into account. The Lemaitre-Chaboche's model, developed upon ABAQUS commercial code, was considered for characterising material behavior. Comparing with experimental data, the proposed approach exhibits good ability in evaluating fatigue crack growth life of cracked attachment lug subjected to different load ratios. The iso-probabilistic P-a-N curves can be used as a practical tool to ensure an optimal maintenance planning for cracked components.

#23 An Engineering Predictive Approach of Kitagawa-Takahashi Diagrams of defective A356-T6 alloy considering SDAS dispersion

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Abstract This study deals with the fatigue life scatter of defective Al-Si Aluminium alloys due to the SDAS (Secondary Dendrite Arming Spacing) dispersion. It proposes an engineering method to generate the Iso-probabilistic Kitagawa-Takahashi Diagrams of defective A356-T6 aluminium considering the modification introduced by varying the SDAS. The proposed approach is carried out by coupling of the DSG (Defect Stress Gradient) criterion, Finite Element (FE) analysis and Monte Carlo (MC) method. In this study, a 3D- FE Analysis considering various defect sizes and load levels using ABAQUS commercial software are carried out. The non-linear isotropic/kinematic hardening model integrated in ABAQUS software is used to evaluate material fatigue response. Comparing with experimental Data, the proposed probabilistic approach gives an efficient tool for characterising multiaxial fatigue life behaviour under alternate tension and torsion loadings considering the random distribution of the SDAS. These Iso-probabilistic Kitagawa- Takahashi Diagrams enable engineers to be engaged in practical problem to estimate the fatigue response in a more safe and efficient way. In addition, the interactions between defect size and SDAS was presented, and their effects on the fatigue resistance were discussed and examined using Response Surface Method (RSM) .

#24 Calculations of fatigue life of a welded joint in the construction of the trolleybus rear axle

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Abstract Strain gauge testing and fatigue life assessment of heavily stressed structural details and parts of trolleybuses are carried out at various stages throughout the development process (Kepka, 2015). The testing locations include several hundred critical locations on the vehicle, tested either during service load simulations on an electrohydraulic test stand or during prototype vehicle rides on actual routes. In the present case, the stresses were measured at a later stage because the part in question (a welded joint in the construction of the rear axle) had not been expected to pose any problems based on previous experience. The data gathered in actual service included information about the part's service life to occurrence of fatigue cracks. By comparing the information from service and the computational prediction of fatigue life, one could find whether the measurement and fatigue calculations would have been a sufficient basis for identifying the part as a critical one if it had been subject to scrutiny early on.

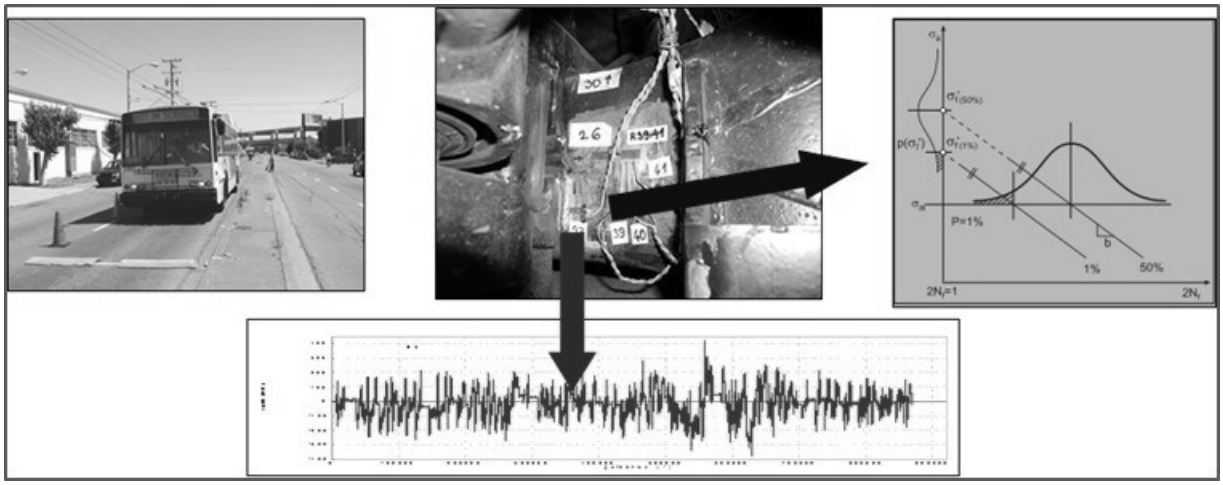

***Figure** – Measurement of stresses in real operation.*

The summary of this basic stage of research is that well-conceived parametric calculations of fatigue life can provide predictions of reliability in service of parts operated under dynamic loads, enable the main adverse factors to be eliminated, and allow the optimization of the part's shape and quality, as well as its workmanship in terms of technological processes.

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

#25 Fatigue strength and fracture mechanics

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Abstract The total life of a component as well as the fatigue limit are based on the S-N curve approach. Whilst the material S-N curve is usually determined on smooth specimens, component S-N curves, besides the specific material, are affected by a number of factors such as different mean stress, notches, surface roughness and impairments, the size of the component, etc. In practical application, those effects are usually taken into account by semi-empirical correction factors on the fatigue limit.

In contrast, fracture mechanics has the potential for implicitly taking into account all those parameters. The transferability problem from test specimen to component is not solved empirically but on a physical basis. However, in common applications e.g. in the framework of a damage tolerance concept, fracture mechanics is restricted to the determination of a residual lifetime, i.e., the time a pre-existing crack needs to grow to its critical size. The dimensions of the pre-existing crack are defined by the detection limit of the non-destructive testing method applied in quality control after manufacturing or in regular inspections in service. They will usually be in the order of millimeters or – in fracture mechanics terminology – in the order of so-called long cracks.

When fracture mechanics shall be applied to the total lifetime respectively the fatigue limit of components (within the meaning of the S-N curve approach) it has to overcome this limitation. More specifically it has to address four challenges:

(a) It has to adequately describe so-called short crack propagation, which cannot be based on the common long crack concepts for principle reasons. Since the crack size is in the order of the plastic zone size, the modelling of short crack propagation cannot be based on the common linear elastic ΔK concept. Instead, an elastic-plastic parameter such as the cyclic J integral has to be applied. A second point is that the crack closure concept has to be modified in that the crack opening stress is not a constant, crack size-independent parameter but shows a transient behavior with increasing short crack size.

(b) It has to provide a meaningful definition of the initial crack dimensions as the starting point for an S-N curve relevant (residual) lifetime analysis. This can be based either on the (statistical) size of material defects which can be treated as cracks or by the size of the crack which would arrest subsequent to early crack propagation, whatever is larger.

(c) It has to cope with the problem of multiple cracks for load levels higher than the fatigue limit such as it occurs in many applications in the absence of very large initial defects.

(d) This requires consequent statistical treatment taking into account variations in the local geometry of the area where crack initiation has to be expected as well as the scatter in the initial crack size and in the material data used for the analyses.

The presentation provides a discussion on all these topics and it offers solutions for it.

#26 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 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.

#28 Finite Element Analysis of Crack Initiation and Crack Growth for Structural Health Monitoring of Mooring Chains

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Abstract: As offshore oil and gas exploration and production goes further afield and into deeper waters, more offshore operations, are conducted from floating platforms, which are moored to the seabed by chains, polyester tether lines, or combinations of both. Moreover, the forecasted large scale deployment of offshore renewable energy systems in deep water will rely upon similar mooring systems. Mooring lines are safety-critical systems on offshore floating and semi-submersible platforms. The lines are usually subject to immense environmental and structural forces such as currents, oceans waves, and hurricanes. Other forces include impact with the seabed, abrasion, increased drag due to accumulation of marine organisms and salt water corrosion. Failure of one or more of mooring lines can result in disastrous consequences for safety, the environment and production.

Mooring chain life can be significantly reduced, leading to unacceptable risk of catastrophic failure, if early damage is not detected. Chain mounted equipment is available to monitor chain tension and bending, but detection of damage caused by stress concentrations, fatigue, corrosion and fretting or combinations of these is not currently possible. The Acoustic Emission (AE) technique can be capable of detecting cracks in mooring chains and fatigue damage. This paper will describe a novel methodology of Finite Element Analysis (FEA) for crack initiation and crack growth simulation for Structural Health Monitoring (SHM) applying AE technology for damage detection (Figure 1).

SHM is the process of implementing a damage detection and characterisation strategy for engineering structures. Damage is defined as changes to the material which adversely affect its performance. The extraction of damage-sensitive features from the very large amount of sensor data normally requires sophisticated statistical analyses.

Because of the inherent uncertainties present in any SHM technique, the AE technology should be applied in conjunction with other available information, including data from periodic inspections, numerical modelling showing stress distributions or crack propagation, historic and current operations.

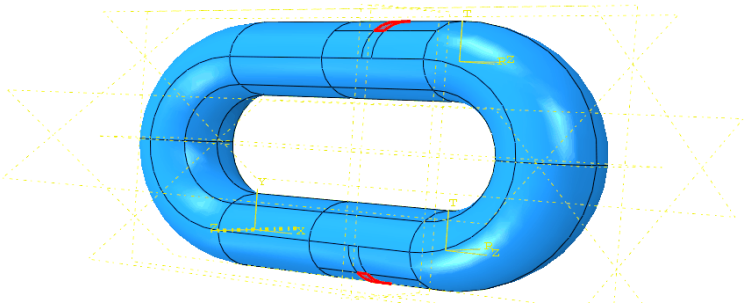

***Figure 1** – Mooring chain model loading, crack geometry and propagation*

#29 Cognitive Sensor Technology for Structural Health Monitoring

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Abstract This paper presents new intelligent technology which may be applied in the field of SHM for automation of analytical processing of data gathered during condition monitoring of technical objects. Proposed numerical technology is based on a model of Cognitive Sensor (CS) which implements methodology of Artificial Subjective Reality (ASR). Cognitive Sensor is the main element of architecture of subsystem which is used in Structural Health Monitoring system for the processing of data streams. CS model is realized as Artificial Neural Network which has time-dependent architecture - Dynamic Artificial Neural Network (DANN). Proposed neural network in general case has several layers of neurons: input layer, output layer and several hidden layers. Structure of network associated with definite CS highly depends upon the experience of data processing by this sensor. Advantages of proposed model include ability to learn both linear and non-linear patterns on the basis of processing of data streams and ability to implement Life-Long Machine Learning principles. Harmony Theory formulated by Smolensky for dynamical systems may be applied for learning of Cognitive Sensors. It may be done by the same way as realized in Helmholtz Machines. Learning of Cognitive Sensor may be realized both by supervised and unsupervised methods. We show that the use of supervised methods for learning of ASR-based networks needs implementation of additional means for the control of learning process. Numerical experiments with DANN reveal how the dynamics of learning is connected with pre-defined parameters of data processing by neurons. In current paper we describe Structural Health Monitoring system which is based on the use of several Cognitive Sensors. We represent the model of this system which is based on principles of self-organization. Dynamics of structure of neural network in this case includes several different stages: separated evolution of DANNs associated with each CS, interaction of different DANNs aiming to construct single neural network, and evolution of cooperative DANN. One of most interesting implementations of CS-based SHM may be represented by the case when system includes several different types of Cognitive Sensors. So that different types of sensors make processing of quantities which have different physical nature. We represent and discuss results of numerical investigation of SHM which includes two different types of sensors. In the final part of the paper we represent the set of most hard problems associated with implementation of CS based systems and discuss future ways of development of intelligent systems on the basis of CS-DANN architecture.

#30 Weak and strong bi-material interfaces and their influence on propagating cracks in plane elastic structures

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Abstract The developing crack paths in crack growth simulations in heterogeneous structures are the result of the inhomogeneous state of stress. The latter is influenced e.g. by inclusions in an elastic matrix, which are bonded either through a strong or a weak interface. Besides the elastic properties of the inclusion, the kind of interface has a decisive influence on the state of stress and therefore on propagating cracks. It is experimentally proven that cracks tend to grow towards regions with lower stiffness [1,2], therefore matrix cracks might be attracted by interface delamination cracks. In this research the matrix crack growth in bi-material structures is simulated, incorporating dissipative processes arising at weak interfaces and a reference is provided by simulating the crack propagation in the same bi-material but with a strong (perfect) interface. Incremental crack extensions constitute the matrix crack growth, requiring a continuous modification of the geometry. An intelligent re-meshing procedure is applied, where the loading history cannot be neglected due to the presence of dissipative processes [3]. The crack deflection and crack tip loading are determined by the J-integral criterion and stress intensity factors, respectively. The resulting crack paths confirm, that the matrix crack tends to grow into the direction of regions with lower stiffness. If weak interfaces are considered, an extremely attracting effect on propagating matrix cracks caused by the delamination is observed, which is stronger than the influence of soft or stiff domains.

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#32 Low durability of concrete elements due to steel corrosion – cases wherein the reinforcement acted as an internal clock bomb

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Abstract: Concrete elements are expected to resist any process of deterioration to remain its original form, quality and serviceability when exposed to its intended service environment. As the concrete deteriorates durability problems progressively develop leading to structural damage, which might put users in a potential danger. Concrete deterioration may be categorized into three categories of causes: physical, chemical, and mechanical, from which major durability issues come from steel corrosion as a result of combined effect of multi environmental factors. In this work the consequences of steel corrosion on concrete elements durability wherein steel reinforcement bars seem to be structurally unnecessary are evaluated and cases of inappropriate construction practices or minimum reinforcement rules are identified.

Figure 1 - *Degradation of constructions due to reinforcement corrosion: a) seat bank / fence between ocean beach and promenade; b) buttress vault; c) concrete block wall with reinforced mortar at the top; and d) concrete fence*

#33 Developing a commercial Self-Compacting Concrete with basaltic aggregate materials

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Abstract: Self-Compacting Concrete (SCC) has been worldwide developed based on the Okamura et al. methodology since 1988. Typically, limestone filler is incorporated to increase powder content and high quality granitic or limestone aggregates are used, with the content and maximum size being limited. Due to its geological origin and its geographical location, there are no granitic or limestone stones in the Madeira Island. Therefore, there is no limestone filler and concrete aggregates (fine and coarse) currently available are crushed and from basaltic origin. The scarcity of the suggested raw-materials to produce SCC conditioned its development in Madeira Island. However demand for concretes with high durability, as well as, with high surface finish quality has motivated the development of SCC in Madeira Island. This paper describes the experimental campaign carried out on the development of a commercial SCC composition, using the materials currently available in the local market. Moreover, it aims to contribute to the establishment of a methodology that leads to optimized compositions to satisfy the performance requirements of the commercial SCC compositions. Several SCC mix compositions were tested (Figure 1); studies being initially carried out on pastes and mortars. The powder content was increased by incorporating fly ash, being the water-to-cement ratio kept low by using a superplascyzer and a plasticyzer. All the aggregates were from basaltic origin; the fine sand was from the ocean and the coarse sand, fine gravel and coarse gravel were crushed. At the end, an optimized SCC composition was validated in real/commercial conditions: it was produced in a ready-mix concrete plant, transported and applied in a real structure wherein self-compacting properties were required due to high reinforcement content. Since no markedly changes were introduced since production up to casting, results were considered satisfactory. Consequently, the concrete plant decided to launch the SCC composition as a commercial product in the Madeira Island.

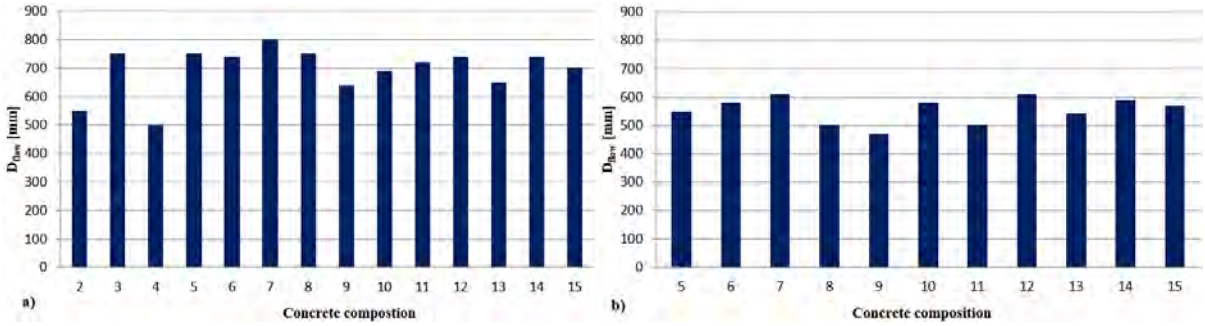

Figure 1 – *D_{flow} – a) immediately after mixing; b) 30 min after mixing.*

#34 Mechanical performance of a confined reinforced concrete beam

Y. Bouamra[1], K. Ait tahar[1]

[1]University Akli Mohand Oulhadj of Bouira, Laboratory LM2D, Algeria

Abstract This study focused on the four-point bending behavior of the concrete beam subjected to an innovative internal axial confinement process. An experimental study was carried out to validate the effectiveness of this technique. The four-point bending tests was carried out on confined concrete beams by this technique which makes it possible to produce an induced a compression stress induced by the normal component of the tensile effort developed in the resistance reinforcement at the level of the anchoring of steel bars. The results show the increasing of the ultimate bending strength compared to the control beam. Two opposing half-cylindrical plates are welded to the level of the curvatures of the steel bars. Each bar has a hook at one end only. The two hooks are arranged in the taut area of the beam and diametrically opposite. This technique allows us to mobilize the confining stresses from the beginning of loading of the beam, contrary to the existing methods, without using other materials as a composite FRP. Furthermore, a theoretical study was proposed to predict the equivalent load to be applied to the reference concrete beam when it is subjected to an ultimate bending moment determinate in the confined concrete beam. The experimental and theoretical results confrontation shows a good agreement.

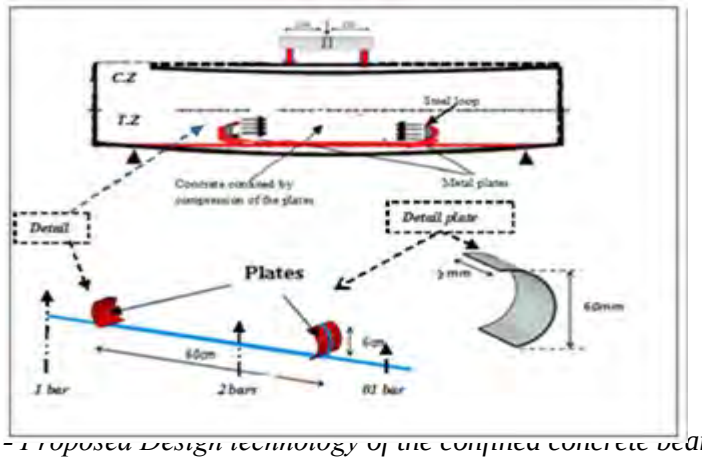

***Figure 1** - Proposed Design technology of the confined concrete beam*

#35 Behavior of damaged concrete cylinders passively confined

B. Moussaoui [1], K. Ait tahar[2], Y. Bouamra[2]

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Abstract This study focused on the behavior of the damaged concrete cylinders passively confined by an envelope constituted by the stack of the polymers tubes bonded by a STR resin under the axial compression load until rupture. The aim is to study the influence of the thickness of the polymer tube and the degree of damage of the concrete on the confinement rate. The compressive load was applied only on the concrete and not on the tube. Three series were considered: concrete cylinders, confined undamaged concrete cylinder and confined damaged concrete cylinder. The concrete cylinder is passively confined by 1, 2 and 3 tubes respectively. All the tubes have the same thickness but different diameters, so that during the stacking of the tubes the clearance between them is rapidly absorbed by the resin to ensure good contact and adhesion between the tubes over the all the circumference of the concrete cylinder. The effect of the radial confinement is shown by the different stress-strain curves depicted for each series of concrete cylinder. Analysis of the results obtained from the various compression tests carried out on the various short concrete cylinders shows that the ultimate stresses at the peak and the corresponding deformations experience an improvement as a function of the thickness of the polymer tube, the lateral confinement pressure does not vary linearly with the thickness of the polymer tube but above all that the confinement effect is higher for the damaged concrete cylinders Comparatively to the undamaged concrete cylinder. In conclusion, passive confinement by polymer tubes is particularly recommended for damaged concrete cylinders and columns.

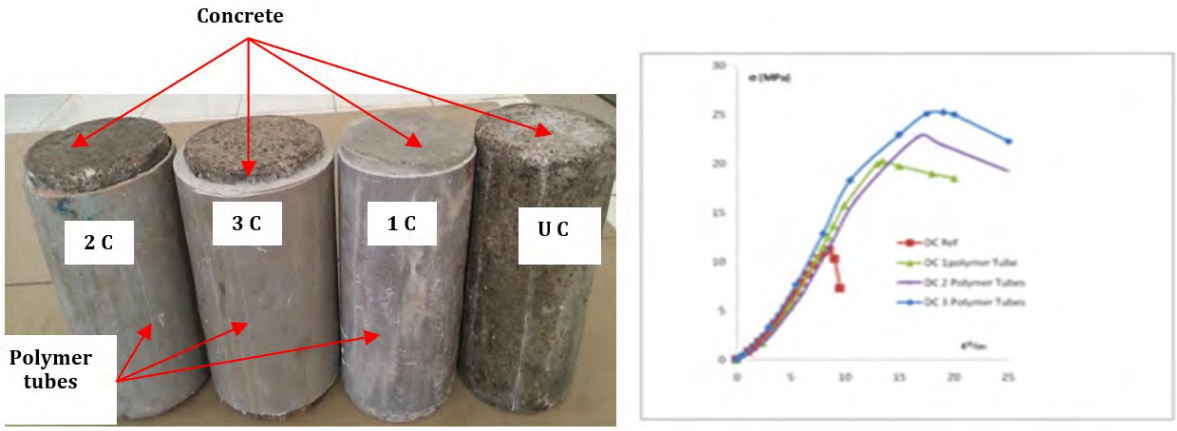

Figure 1 - *The various confined concrete cylinders by polymer tubes and stress–strain curves of confined damaged concrete cylinders*

#37 FE Mesh Generation – Automated Crack Grow Modeling with a View to Stress Intensity Factor Computing

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The damage tolerance design approach, expects the existence of the initial flaw in any structure. To manage the extension of this flaw during service, the fracture mechanics principles are applied. For this purpose, two domains of analysis must be accomplished: First, the crack growth due to variable, periodical load (fatigue load), second, the residual strength of the damaged structure statically loaded. For both analysis, the computing of the fracture mechanics characteristics in each state of the crack opening is indispensable.

In practice, the application of the FE method is necessary. By the help of currently used FEM software NASTRAN, the stress intensity factor – K_I and K_{II} – can be compute by application of the special element, called CRAC2D. Unfortunately, CRAC2D element is not implemented into the currently used FE pre-processors. Moreover, one application of the CRAC2D element result only in a single value of the K_I and K_{II} for the modeled crack length.

For these reasons, the fully automated crack growing modeling was developed. Based on the virgin FE model (base FE model without crack), the developed software application generate the appropriate FE model for each desired crack opening. User have only to indicate the crack initiation node and the crack growing trace, so-called crack growing scenario (see fig.1). After the data check, the crack is modeled, the CRAC2D element is applied at the crack tip, the FE model is saved, the related job is executed and the resultant K_I and K_{II} values are associated with modeled crack length. This step is repeated for each desired crack opening.

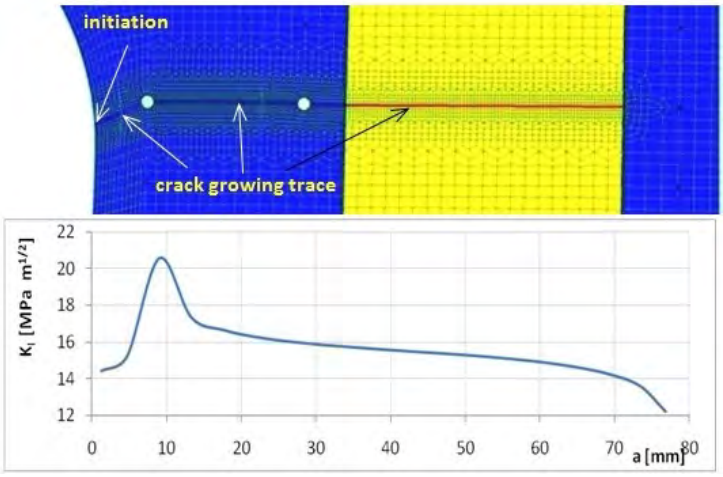

Figure 1 - *Stress intensity factor vs. crack length – crack grow modeling example*

At the conclusion, the presented software application, based on the virgin FE model and the crack growing scenario, generates fully automatically the appropriate FE model for each desired crack opening and finally, determines the stress intensity factor as a function of crack length (see an exemple on fig.1).

#39 Numerical modeling and testing of mechanical behavior of AM Titanium alloy bracket for aerospace application

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Abstract The numerical modelling of the material mechanical behavior of Additive Manufacturing (AM) components is a critical topic in component structural analysis. Experimental results show that AM components are often affected by widespread porosity/low density areas and anisotropy, due to the manufacturing process; although many efforts are being made in order to improve process parameters, inhomogeneities often occur.

Aim of this paper is the numerical simulation of mechanical behavior of an AM component by means of a homogeneous material constitutive model by means of Finite Element Analysis (FEA).

The analyzed component is a geometrically complex structural bracket (figure 1) for aerospace application, re-designed through topology optimization and then produced in Ti-6Al-4V by AM. Main issue is constitutive material modelling, because of the large number of porosity/low density areas detected by tomographic analysis on the component. Despite these manufacturing irregularities, an isotropic and homogeneous material model was used. For modelling procedure validation, a testing activity was performed. In this frame, in order to assess main mechanical properties of the material, tensile and fracture toughness tests on specimens were compared to literature data.

Static and fatigue tests were performed on the component, according to real operating conditions. In spite of the manufacturing irregularities, the components fulfill the requirements of the specific application, in terms of mechanical resistance and fatigue life. Finally, FEA results agree with experimental measurements.

Figure 1 - *bracket*

#40 Tagus river centenarian steel bridges' rehabilitation

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Abstract This paper refers to the rehabilitation design projects and undertaken works of three centenarian steel/ iron bridges executed in Portugal and belonging to the national road network, namely Abrantes' Bridge, Belver's Bridge and Chamusca's Bridge the three of them crossing the Tagus river.

Their typology is basically a steel deck executed in steel or iron elements with rivets that are connected in trusses. These three examples cover upper and lower decks.

The original platforms were generally made of wood and lately were changed to reinforced concrete slabs to meet traffic necessities. The decks are supported by piers and abutments made of masonry as well as wing walls when existing.

In this paper each bridge is analysed in detail, highlighting its main anomalies which distinguish it situation from the other ones and the purpose of the repair and the reinforcement works that were prescribed.

The existing situation before the intervention is characterized through bridge inspections both principals and special and also through the main conclusions obtained from laboratory tests over samples extracted from precise points of the structures.

The hypotheses for the intervention in order to upgrade each structure to actual regulatory actions are discussed in terms of (i) present restraints, (ii) difficulties of execution due to the lack of resistance of existing materials (for instance non-weldable iron) or particular geometry of the elements or complex connections involving composite members and rivets or even (iii) aesthetics issues regarding patrimonial heritage.

Important factors and curiosities observed during their rehabilitation design and works are also summarized. Namely the case of global reinforcement of a structure achieved with the reformulation of the external pre-stress and the elimination of joints in the upper slab and also the case of reinforcement of a non-ductile structure to the seismic action.

The paper ends with a brief conclusion about the major problems that affect this kind of structures though their long existence. The nature of their constitution, the original conceptual design and the influence of its assumptions in the global behaviour of the structures, the difficulty to estimate quantities of repair in the early stages of the intervention (during project-time) where no pickling process has yet started and real deficiencies are covered with paint, the thorough work necessary to add the compulsory resistance preserving its aesthetic and heritage, among other remarks.

#41 On strength analysis of highly porous materials within the framework of the micropolar elasticity

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Abstract We discuss the finite element approach to modelling of static deformations of porous materials such as foams, beam lattices, and others within the micropolar elasticity. It is known that the micropolar elasticity may be used for microstructured solids and fluids since it can forecast size-effect near geometrical singularities such as holes, notches, small contact areas of two solids. Within the micropolar elasticity the translational and roatational interactions of the articles can be into account.

Here we present the recent developments in the theory of finite elements calculations for micropolar solids in order to capture the stress behaviour in the vicinity of geometric singularities such as holes, notches, imperfections or contact areas. The fundamental equations of the micropolar continuum are presented. The FEM implementation in micropolar elasticity is given. The new 8-node hybrid micropolar isoparametric element and its implementation in ABAQUS are introduced. The solutions of few 3D benchmark problems of the micropolar elasticity are given. Among them are analysis of stresses and couple stresses near notches and holes, contact problem of parabolic stamp and half space. The main attention is paid to modelling of interaction between a biodegradable porous implant and a trabecular bone. Comparison of classical and micropolar solutions is carefully discussed. Comparison of classical and micropolar solutions is discussed. Numerical tests have shown that couple stress appears almost in the vicinity of geometrical singularities. It is shown that micropolar elasticity allows to obtain better results for domains with microstructures and singularities than classical theory of elasticity.

Authors acknowledge the support by the People Program (Marie Curie Curie ITN transfer) of the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No PITN-GA-2013-606878.

#42 Failure investigation of the crankshaft of diesel engine

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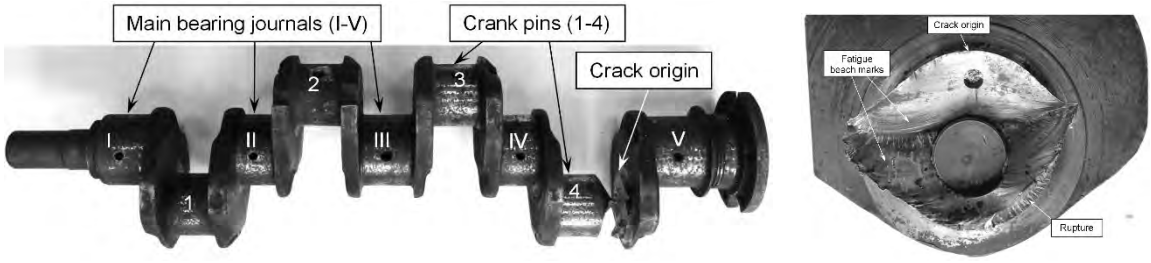
Abstract In this work the failure analysis of the crankshaft (Fig. 1a) of a diesel engine was performed. Visual examination of the crankshaft fracture (Fig. 1b) showed that the beach marks, typical for fatigue failure were observed. Additional observations of the crack initiation zone indicated that the crack origin was not covered by the material defects or the corrosion products. The main objective of presented investigations is explanation of the crankshaft failure reasons. An additional aim of this work is determination of the stress state in the crankshaft during the work of the engine.

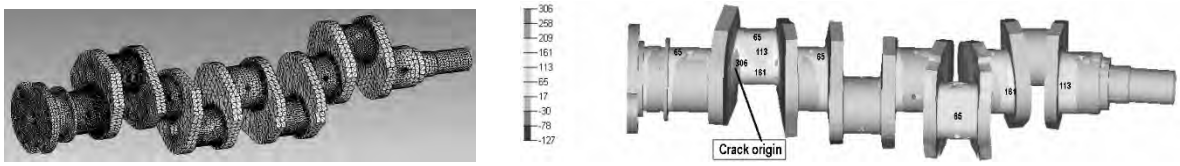


a) *b)*

Figure 1 - *View of the crankshaft after failure (a) and fracture of the crankshaft (b).*

The crankshaft after failure was subjected to the material investigations (microscopy analysis, tension and hardness test of specimens cut from the shaft).

In order to explain the reason of premature crankshaft damage, the finite element method was additionally utilized. In Figure 2a the numerical model of the crankshaft was presented. In analysis the complex boundary conditions were defined in order to simulate the interaction of the crankshaft with the connecting rods and the main bearings. In results of nonlinear finite element analysis the stress distributions in the crankshaft subjected to the complex operational loads were obtained. In second part of the numerical computations the modal analysis of the crankshaft was additionally made. Result of this analysis (Fig. 2b) showed that location of the maximum stress zone (for mode II of free vibrations) coincides with the crack origin (Fig. 1).



a) *b)*

Figure 2 – *Finite element model of the crankshaft (a) and maximum principal (σ_1) stress distribution in the crankshaft during free vibration (mode II, amplitude A=0.1 mm) (b).*

Acknowledgement

The research leading to these results has received funding from the People Programme (Marie Curie International Research Staff Exchange) of the European Union's Seventh Framework Programme FP7/2007-2013/ under REA grant: PIRSES-GA-2013-610547.

#43 Optimizing of MAT method for local wall thinning problems

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Abstract For pipes used in industry, wall thinning is one of the most serious defects. The detection and the evaluation of the thickness reduction of pipes are very important issues for the prediction of lifetime of the pipes in order to avoid severe accidents. A recently developed nondestructive method called Magnetic Adaptive Testing (MAT), which is based on systematic measurement of minor magnetic hysteresis loops, was successfully applied for detection of local wall thinning in ferromagnetic plates. It was shown that even a relatively small, local modification of the sample thickness could be detected with adequate signal/noise ratio from the other side of the specimen.

For the optimization of this method, the magnetic flux distribution in the magnetic circuit (which contains the magnetizing yoke, the air gap between sample surface and yoke and the sample itself to be magnetized) was simulated. A ferromagnetic steel plate (500x300x6 mm size) was used for simulation, which contains different size artificial slots in the bottom, while magnetization takes place from the top. Magnetization of the plates was performed by an attached magnetized yoke on the top of plates. The change of the magnetic flux density – due to the presence of the artificial slot – was calculated in the cross section of the magnetizing yoke as function of the size of the defect and of the distance between the legs of yoke. Result is shown in Figure 1. Parameter is the cross section of the 300 mm long slots.

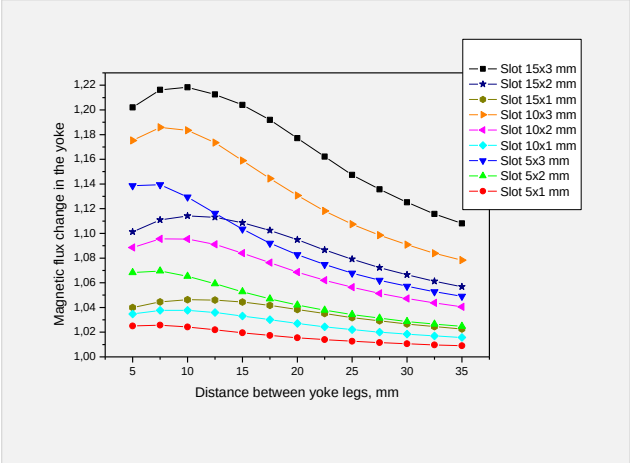

***Figure 1** – Modification of the magnetic flux density due the presence of different size slots as functions of the size of magnetizing yoke.*

The result of simulation helps to find the optimal parameters of the experimental arrangement, mainly the size of the magnetizing yoke. Good correlation was found between results of calculations and experimental results, verifying such a way the simulation.

#45 An infrared thermography model to estimate depth and thickness of hidden corrosion in assembly elements

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Abstract The presence of corrosion in assembly components is a serious problem for industrial installations, it can have frightening technical and economic consequences. Visual inspection is sometimes inefficient and insufficient to determine the hazardous condition of corroded metal joints. In order to safeguard and regularly monitor certain assembly elements subjected to heavy stresses, We propose in this article a model allowing to estimate by infrared thermography the depth and the thickness of hidden corrosion between two steel assembly elements. This model is based on three-dimensionals finite element method. Its results exploitation ensures maintenance before a critical threshold of the dimensions of defect is reached. The geometric dimensions of the hidden rust layer are taken into consideration.

Key words: 3D finite element method, infrared thermography, depth, corrosion thickness.

#46 Nano-mechanical testing of brittle materials

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Abstract The deformation and fracture behavior of differently oriented WC grains/crystals in WC – Co, Si3N4 grains/crystals in reaction bonded Si3N4 system and ZrB2 grains/crystals in ZrB2 polycrystal were investigated. Depth-sensing nano-indentation and scratch tests of grains and micro-compression tests of micropillars prepared by focused ion beam from oriented facets of grains were studied at room and high temperatures. Electron backscatter diffraction (EBSD), atomic force microscopy (AFM) and scanning electron microscopy (SEM) investigations were performed to determine the grain orientation and to study the surface morphology and the resulting deformation and damage mechanisms around the indents and in micropillars.

The hardness and scratch resistance of the differently orientated grains showed significant angle dependence from the basal towards the prismatic directions. A strong influence of the grains orientation on compressive yield stress and rupture stress values was found during the micropillar test, too. The active slip systems for individual ceramics have been recognized.

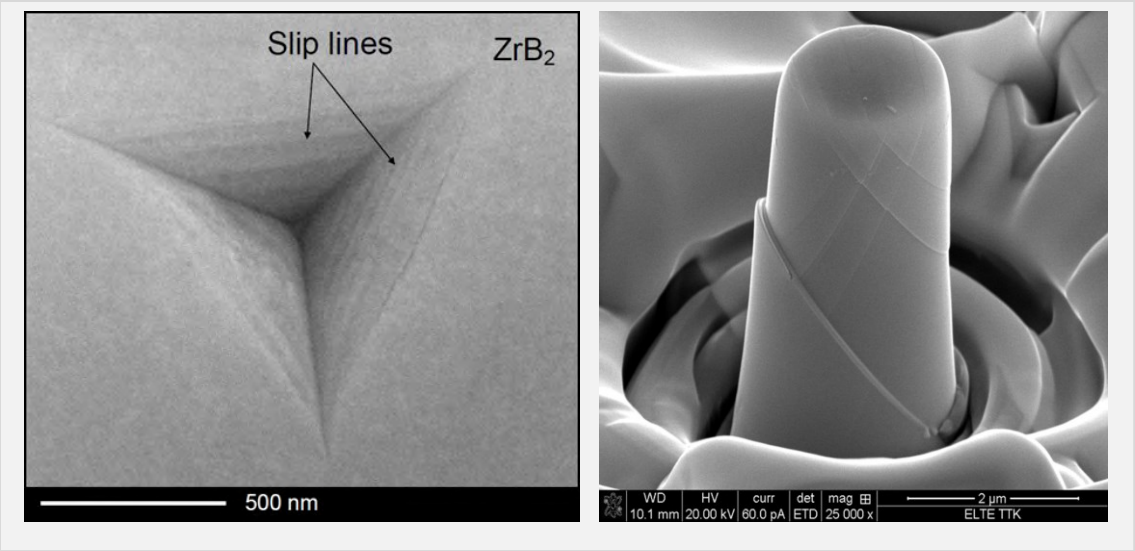

Figure 1 - *Slipe lines in ZrB2 and WC originated during nanoindentation and micropillar test*

#47 Elevated temperature design evaluation program, HITEP_RCC-MRx and its applications to a sodium-cooled fast reactor

Hyeong-Yeon Lee[1], Min-Gu Won[2], Nam-Su Huh[3], Woo-Gon Kim[1], Ji-Young Jeong[1]

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[2]Sungkyunkwan University, Department of mechanical engineering.

[3]Seoul National University of Science and Technology, Mechanical engineering department.

Abstract For integrity evaluation of high-temperature components in Generation IV nuclear systems such as sodium-cooled fast reactor (SFR), lead-cooled fast reactor (LFR) and very high temperature reactor (VHTR), application of elevated temperature design (ETD) rule is required. In this study, programming of the international ETD rule, RCC-MRx has been conducted so that design-by-analysis (DBA) according to RCC-MRx procedure can be conducted in an efficient and reliable way. It has been developed so DBA according to RB-3200 and design-by-rule according to RB-3600(piping) can be reliably conducted. The web-based program of the HITEP_RCC-MRx runs on a smart phone as well as on a personal computer. The HITEP_RCC-MRx has been applied for the design evaluation of the main components in a large-scale sodium thermal-hydraulic test program called the STELLA (Sodium Test Loop for Safety Simulation and Assessment). Fig. 1 shows the first screen of the HITEP_RCC-MRx program. Fig. 2 shows stress intensity profile in model reactor vessel (RV) of the STELLA-2 sodium test facility. The evaluation results on creep-fatigue (C-F) damage using HITEP_RCC-MRx were well within the design limits as shown in Fig. 2. Verification of the HITEP_RCC-MRx has been conducted with 6 pressure vessels and 5 piping systems, and first phase of verification on the HITEP has been completed. Verifications on the HITEP_RCC-MRx have been performed with comparisons of the two results from the HITEP program and direct calculations using excel as per RCC-MRx. The two results on load-controlled stress, inelastic strain and creep-fatigue damage were in good agreement as shown in Fig. 2. Third party verifications on the HITEP program have also been conducted.

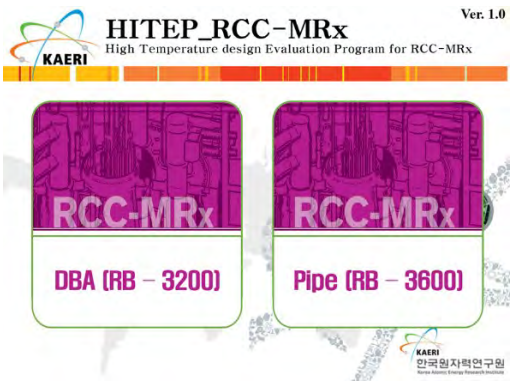
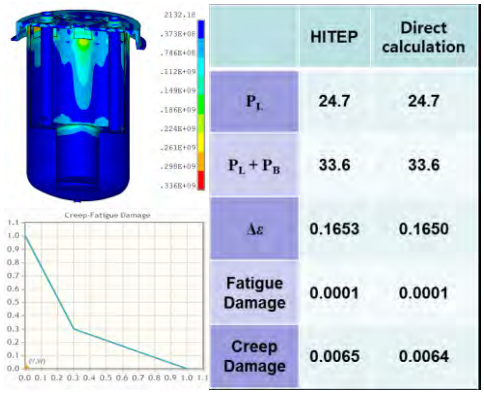


Figure 1 - *First screen of the HITEP_RCC-MRx*



	HITEP	Direct calculation
P_L	24.7	24.7
$P_L + P_B$	33.6	33.6
$\Delta\varepsilon$	0.1653	0.1650
Fatigue Damage	0.0001	0.0001
Creep Damage	0.0065	0.0064

Figure 2 - *Design evaluation of model RV*

#48 Torsion vibrations monitoring of turbine shafts

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Abstract High torsionally induced stresses, relative to the high cycle fatigue strength, caused due to an abnormal event or the torsional resonance can occur on LP turbine blades and in the machine shafts at areas of stress concentration and are the reason of major fatigue fractures in several power stations.

The objective of this article is to describe the on-line measurement system, which was installed in one of Czech nuclear power stations for continuous monitoring of torsional vibrations of the turbine-generator and to give some results, obtained from more than four years system operations. The goal of the measurement system is to look for high stress peaks, calculate the basic rainflow matrix applicable for damage accumulation estimation at desired point on the structure and follow the specific frequencies in the torsional spectra, which can be responsible for or can detect the damage of LP turbine blades.

The system is based on measurement of sheer strains using resistance strain gauges and telemetry supply and data transferee. Daily data are stored in hard disc in separate files. The data reduction, consisting of daily statistics calculation, moving average histories creation (segmentation over 10 s) , rain-flow matrices calculation, spectrograms calculation and peak finding as well as spectrogram calculation for high torsional excitation is performed each day. The data reduction is about 1:100. The daily reports obtaining important data are created each day as well. A special procedure was developed for tracking the changes of desired resonance frequencies, e.g. of turbine blades, or of the shaft due to the crack development in the torsional spectra.

The application is running on power station server on virtual operation system with RDP access as well as on separate computer connected to the network.

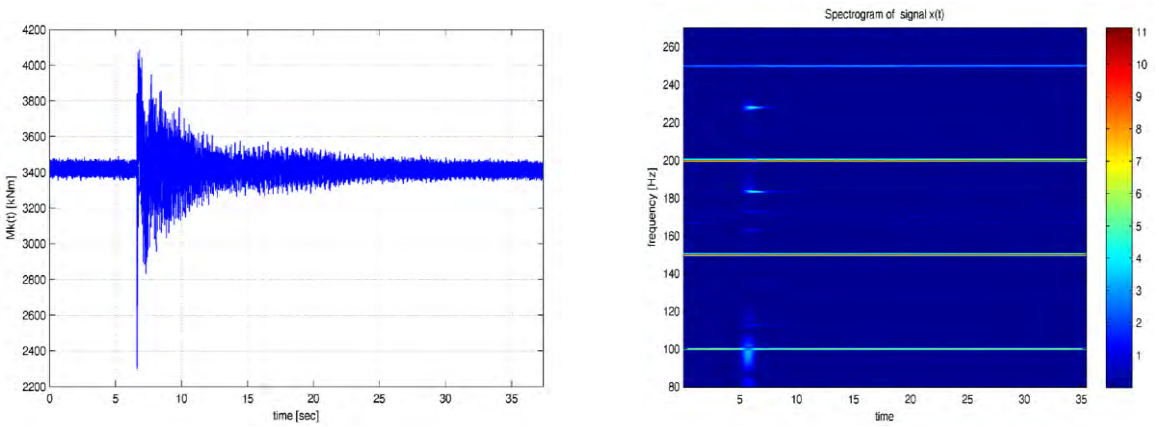

***Figure 1** – An example of abnormal torsional event and its spectrogram with visible excited resonance frequencies*

The contribution is originated in the framework of the Centre of the competency of Technical Agency of Czech Republic, TA ČR TE01020068: “Centre of research and experimental development of the reliable power industry”.

#49 Proposal of a stress-based isothermal LCF life model for Aluminium alloy cylinder heads

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Abstract Due to its very complex geometry, cylinder head is generally obtained by a single cast of primary aluminium alloys for high performance and diesel engines, secondary aluminium alloys for gasoline engines, and cast iron for several industrial engines.
Aim of the paper is to present and discuss the calibration procedure at room temperature and the results related to a new easy-to-use LCF life prediction empirical stress-based model, applied to an Aluminium alloy commercial diesel engine cylinder head.
The characterization is carried out on cylinder heads manufactured in AlSi9Cu1 primary aluminium alloy, which was characterized investigating the mechanical properties on many sets of specimens obtained from layers positioned at different distances from the fireplate. In figure 1 the adopted cutting layout is reported. The results of mechanical characterization and LCF model calibration parameters are presented for each layer.
The characterization was carried out at room temperature to assess the procedure and validate the model. Further characterizations at different temperature will allow to validate and discuss the temperature dependence of the model parameters and to investigate the TMF life assessment performance of the model.
The life assessment model performance is compared with the corresponding Manson-Coffin model. Damage model prediction fitted experimental data trend with a determination coefficient ranging from 0,75 to 0,98; this fitting is globally higher with respect to the parameter fitting obtained for the Manson-Coffin calibration. Furthermore, all life forecasts are close to the experimental results with a variance lower than 40%.

Figure 1 – *Layers locations for specimen preparation*

#50 Improvement of corrosion resistance of AZ-91E magnesium alloy by plasma electrolytic oxidation

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Abstract Magnesium alloys have been considered as one of the most promising lightweight materialswith potential applications in the automotive andaircraft industry.However,poor corrosion resistance preventsthem from wider implementation. Plasma electrolytic oxidation (PEO) is a novel surface treatment that enables overcoming these limitations. Two series of coatings were formed on a AZ-91E magnesium alloy in the function of the intensity and frequency of the current.The surface morphology, cross-sectional microstructure, chemical and phase compositions of PEO coatings were determined using scanning electron microscopy (SEM) equipped with energy dispersive X-ray spectroscopy (EDS). The chemical composition of the naturally formed oxide film on a sample surface was determined by X-ray photoelectron spectroscopy.Additionally,angle measurements of wetting via polar water and non-polar diiodomethane were performed. Based on these results surface free energy (SFE) was calculated for each sample. Determined physical properties and morphology of the coatings were correlated with results of corrosion resistance in a salt spray corrosion test (SSCT). Moreover, an attempt to enhance corrosion resistance via various coating sealing processes was made.

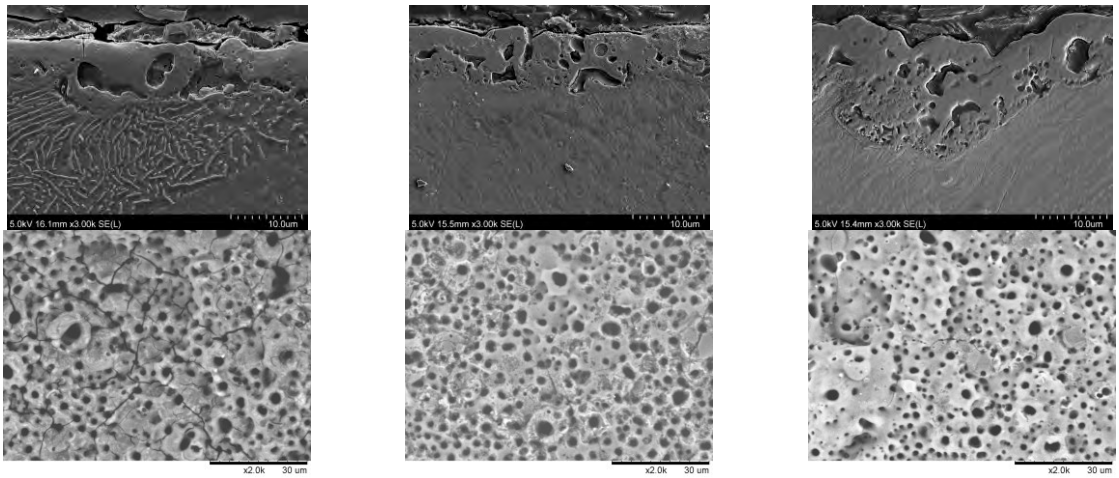

Figure 1 – *Cross section (upper row) and surface (lower row) SEM images of magnesium alloy AZ-91E treated by Plasma Electrolytic Oxidation using various current parameters*

#51 Fatigue strength of welded joints under multiaxial non-proportional loading

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Abstract As is well-known, T-joints concentrate high stresses in the vicinity of the welding, where fatigue crack initiation and propagation due to cyclic loading occur. Hence, a reliable fatigue assessment is needed. Under uniaxial cyclic loading, fatigue assessment can be carried out through different approaches available in the literature, some of them being recognised by Standard Codes and Recommendations: the nominal stress approach (global approach), the structural stress approach (intermediate approach between global and local one), and the notch stress approach (local approach). Under multiaxial fatigue loading, different methods have been proposed and, among them, those based on the critical plane concept. In this scenario, the aim of the present work is to show that the critical plane-based criterion proposed by Carpinteri et al. [1-3] can be applied in terms of notch stresses to perform the fatigue assessment of T-joints in an agricultural sprayer "H" component [4]. Each T-joint consists of a chord with a rectangular hollow cross-section and a brace with a cylindrical hollow cross-section, both of them made of C25E steel. The end of the brace is welded on the chord by a fillet weld. Similar to the critical distance approach by Taylor, the above criterion is applied to some material points characterised by certain distances from the weld toe.

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#52 Domination of self-heating effect during fatigue of polymeric composites

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Abstract A self-heating effect, occurring in polymeric composites during vibrations or cyclic loading due to viscoelastic nature of polymers used for such composites, is a very dangerous phenomenon, which, under certain conditions, may dominate fatigue process and significantly intensify degradation processes of a loaded polymeric structure. Due to dissipative processes of mechanical energy delivered to a structure, there occurs intensive heating. The heat is additionally stored in the structure since most polymers used in manufacturing of industrial composites are characterized by very low thermal conductivity. The resulting temperature is strongly related to stress, thus the higher the stress the higher value of a self-heating temperature it is. According to this, the self-heating effect may develop following two scenarios: the first scenario assumes a growth of a self-heating temperature until reaching a specific value, and then, its stabilization or very slow linear growth (caused by mechanical degradation); while the second scenario assumes domination of the self-heating effect in fatigue process, which results in sudden degradation of a structure until reaching a limit strength and failure. When the self-heating effect dominates fatigue process, damage initiation and propagation occurs at much lower value of temperature than the temperature reached during failure, which intensifies this process.

The following study focuses on investigation of influence of a self-heating temperature value on fatigue process and, in particular, on a criticality of this effect. The main goal of the study is to find a temperature value at which its growth becomes non-stationary (and thus dominates fatigue processes) and investigate an influence of selected self-heating temperature values on fatigue life of a composite structure. The investigation is based on experimental studies, during which specimens were subjected to cyclic loading with simultaneous measurement of loading force, deflection velocity, surface temperature and acoustic emission. Such measurements allow for accurate evaluation of differences between particular loading cases as well as determination of characteristic points (moments) of degradation initiation, and finally analyzing all of measured parameters within a number of cycles to failure. Based on the obtained results it was found that self-heating effect can be dangerous to cyclically loaded composite structures even at relatively low self-heating temperature values and may significantly shorten structural lifetime.

The obtained results of the study on domination of the self-heating effect and its criticality can be very helpful at the design stage of composite structures that are subjected to cyclic loading as well as at the stage of operation of such structures in order to define loading limits properly, which, considering the self-heating effect and its influence on fatigue processes, are much lower than static strength limits.

#53 Modeling of barium titanate microstructure based on both the boundary element method and homogenization technique

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Abstract This paper presents the results of research undertaken to develop a grain boundary element (BE) formulation for the micromechanical analysis of multilayer barium titanate ceramics. The BE formulation of the elastic problem is generated for the single grains of the polycrystalline barium titanate ($BaTiO_3$) ceramics. In order to obtain the $BaTiO_3$ powder the solid-state technique was applied. The microstructure of sintered $BaTiO_3$ powder (Fig. 1a) was examined in detail using scanning electron microscope. Furthermore, the image processing techniques and some of numerical algorithms which was employed in order to discretise the grains boundaries of ceramics (Fig. 1b). The single crystals of homogenous $BaTiO_3$ are represented as anisotropic elastic regions. A comprehensive numerical code along with image processing techniques is generated in order to discretise the boundaries of grains and obtain the exact coordinates of elements on the boundaries. Averaging thorium is developed for obtaining macro stress and macro strain. Numerical results show that developed method is valid in analysing of polycrystalline materials. The results of numerical homogenization of the 2D polycrystals confirmed the effectiveness of developed technique. The numerical investigations also show that the developed algorithm is accurate enough to investigate the multilayer piezoelectric actuator. It is also found that the position of interface as well as the type of materials play an important role in determining effective properties of the multilayer actuator.

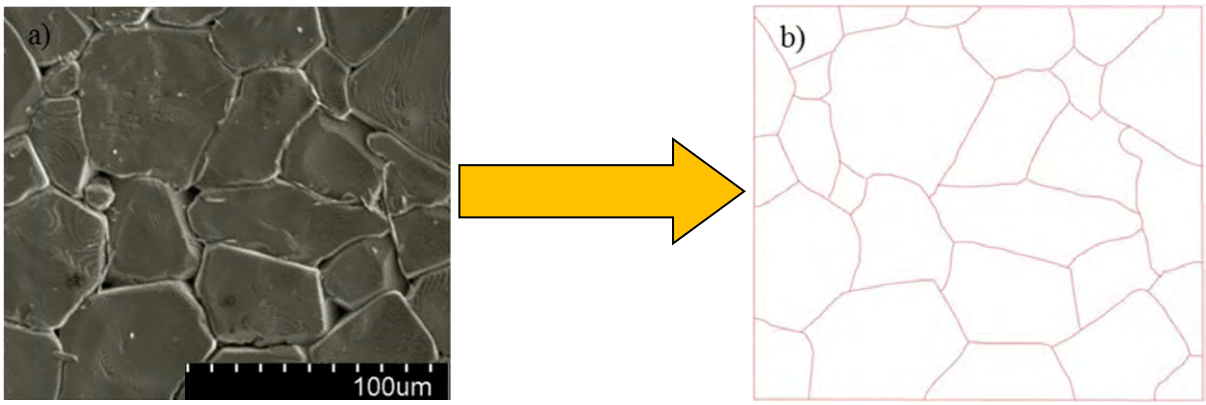

Figure 1 - The SEM microstructure of $BaTiO_3$ ceramics (a) and numerical model of grains

Acknowledgements

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#54 Formulation of CTOD design curve considering the yield to tensile ratio

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Abstract The CTOD design curve approach is one of the fracture assessment procedures for estimating the crack tip opening displacement (CTOD) as an elastic-plastic fracture driving force, and is used for the assessment of flaws in welded structures. The Japan Welding Engineering Society (JWES) has issued WES 2805, "Method of assessment for flaws in fusion welded joints with respect to brittle fracture and fatigue crack growth", and this Fitness-for-Service Code gives a semi-empirical CTOD design curve, where CTOD is calculated from the local strain around the flaw, the flaw size and the yield strain of the material. CTOD should be estimated by using all the factors influencing the crack driving force in the welded joint, but the yield to tensile ratio (*Y/T*), which relates to strain hardening behavior, is not used for the CTOD design curve. On the other hand, JWES issued the new CTOD toughness testing standard, WES 1108 in 2016, where *Y/T* affects the opening shape of the crack tip, and is used for the new CTOD calculation formula of single edge notch bend (SE(B)) specimens. Consequently, there is a mismatch in CTOD calculation between welded structures and SE(B) specimens.

In this study, *Y/T* was considered for CTOD design curve formulation. 3-D elastic-plastic finite element analysis was utilized for obtaining CTOD of a surface toe crack in a corner boxing fillet welded joint for four different *Y/T* steel models. The newly formulated CTOD design curve contributes to a good CTOD estimation for each *Y/T* welded joint.

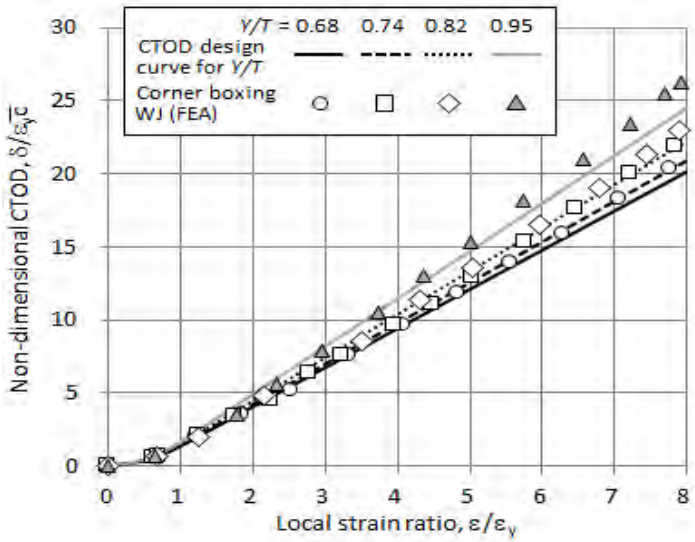

***Figure 1** – Effect of the yield to tensile ratio on CTOD for a corner boxing fillet welded joint.*

#55 Material Influence on Crenellation Effectiveness in Damage Tolerant Design

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Abstract Crenellation is a novel concept to heighten the fatigue resistance of the airframe structures without increasing weight [1-2]. In this work the impact of materials on the effectiveness of crenellations was investigated. Two candidate alloys for future fuselage skin: AA2139 and AA2198 were selected for this task. Firstly the microstructure and texture of those materials were investigated. Then flat and crenellated panels made of the two alloys were tested under service-related biaxial loading conditions (Fig. 1(a-c)). A removable δ_5 clip gauge was applied at the crack tip to monitor the crack closure behaviour during the fatigue tests. After tests the fracture surfaces were examined under SEM and laser-scanning microscope to interpret the respective fatigue behaviour. It was found that sharp textured AA2198 alloy, which also showed tortuous shear lip morphology, has higher fatigue resistance and larger fatigue life improvement of crenellations compared with the randomly textured AA2139 alloy (Fig. 1(d)). The correlation between the sharp texture and tortuous shear lip morphology was discussed. The source of the additional fatigue resistance and the increased crenellation efficiency in AA2198 was also analysed.

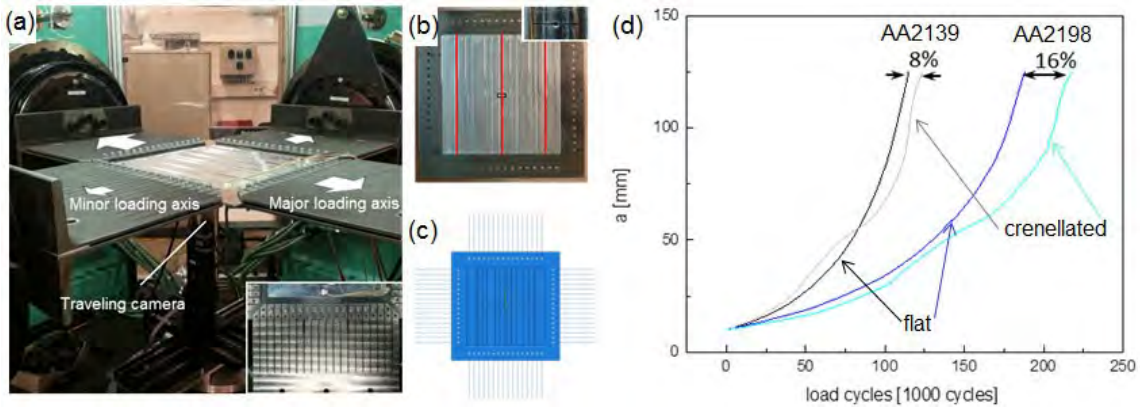

Figure 1 - *(a) Experimental setup, (b) specimen, (c) corresponding FEM model and (d) the fatigue performance of flat and crenellated panels with two different materials*

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#56 Crack path prediction in fiber reinforced composites

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Abstract Composite materials exhibit beneficial features compared to conventional engineering material, e.g. a comparable strength and a reduced weight at the same time. To fully exploit these beneficial properties within technical structures fracture mechanical concepts must be taken into account. The global fracture behavior in composite materials is related to the local delamination at interfaces between matrix and inclusion as well as the local fracture behaviors of the constituents. Because of their structure, the global elastic and fracture mechanical properties of composites are in general anisotropic. In this work, the directional crack resistance of polypropylene (PP) containing a certain amount of glass fibers (GF) or cellulose fibers (CF) is measured. A crack deflection criterion based on the maximum energy release rate is introduced and implemented into a crack growth model. The *J*-integral [1] is applied to calculate crack tip loading quantities on a global level, excluding all numerically inaccurate values at the crack tip [2]. With this approach crack paths in anisotropic aluminum alloys are precisely predicted [3]. Crack growth simulations at compact tension (CT)-specimens of PP with GF and CF are carried out, showing good agreement with the experiments [4]. Several effects resulting from the directional crack resistance are investigated and explained, e.g. a crack deflection at mode-I loaded specimens.

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#57 Longitudinal bonded joints of timber beams using plywood and LVL plates

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Abstract The growth of timber use in building industry brings new trends, not only into the field of innovative wood-based materials but also into joining of the timber structures elements. Besides the already well normatively described longitudinal joints of bending beams with dowel-type steel joints and steel plates or glued-in steel rods it is possible to design longitudinal joints of these structures with internal or external bonded wood-based plates that can be used with no emphasis on the aesthetic aspect. Longitudinal joints of structural dimensions with external bonded wood-based plates in beams loaded with bending moment were chosen for laboratory testing (see Fig. 1). Material of these plates is LVL and plywood. Two component epoxy adhesive was used for bonding of wood-based plates. The bearing capacity of these bonded joints of wooden beams was determined by laboratory four-point bending tests, by numerical modeling and also by analytical calculation. The results show good agreement between laboratory tests and numerical models.

The aim of this article is in description of typical rigidity and carrying capacity of this type of joints.

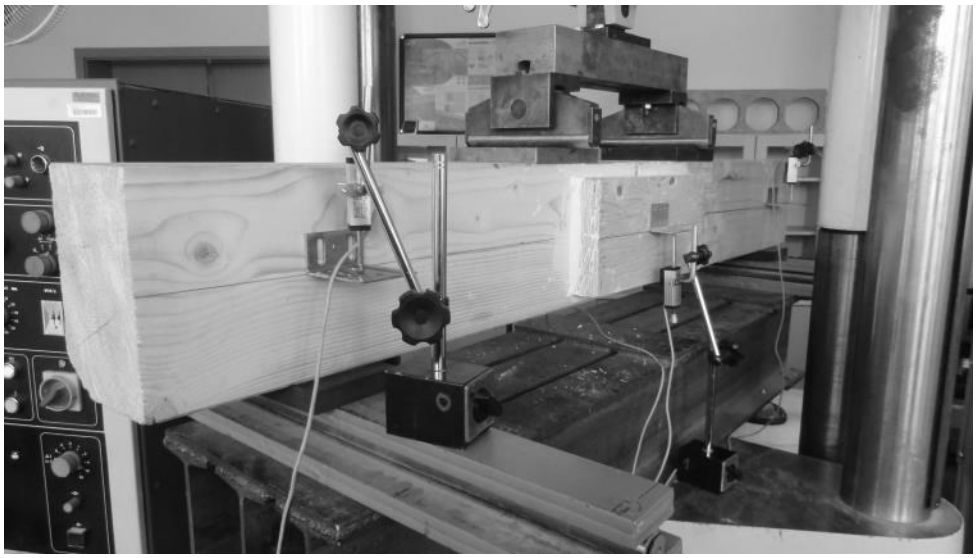

Figure 1 - *Timber beam with bonded joints and LVL plates in testing machine*

#58 Wear damage of TiTaCN-Co cermets at room and elevated temperatures

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Abstract The work is focused on microstructure, mechanical and tribological properties of TiTaCN-Co based complex solid solution cermets with different graphite addition (0, 1.8, 2.2 %) with the typical use as cutting tools. The materials were prepared by the way of mechanochemical MSR (mechanically induced self-sustaining reaction), using a high energy milling of the starting constituents - Ti, Ta, C, and Co in nitrogen atmosphere. Then they were compacted by cold isostatic pressing and sintered at 1500 °C. Microstructure of the obtained materials was studied by SEM/EDX amd assesed by image analysis. Hardness and indentation toughnes were evaluated using Vickers indentation. Tribological tests were carried out on the high temperature tribometer THT Tribometer (CSM Instruments) to obtain friction coefficient. Ball-on-disc method was used. Wear testing was carried out under following conditions: normal load 5N, sliding distance 300 m, linear sliding velocity 0.1 m/s, atmosphere: air, temperature – 25 °C, 200 °C, 400 °C, tribological static partner – WC-Co ball and steel ball with 6mm radius. Created wear track was observed using scanning electron microscopy to identify wear mechanisms. Area of the wear track cross-section was measured using 3D optical profiler (SENSOFAR Plu neox) and the specific wear rate in terms of the volume loss was calculated according to the international standard ISO 20808 Fig. 1.

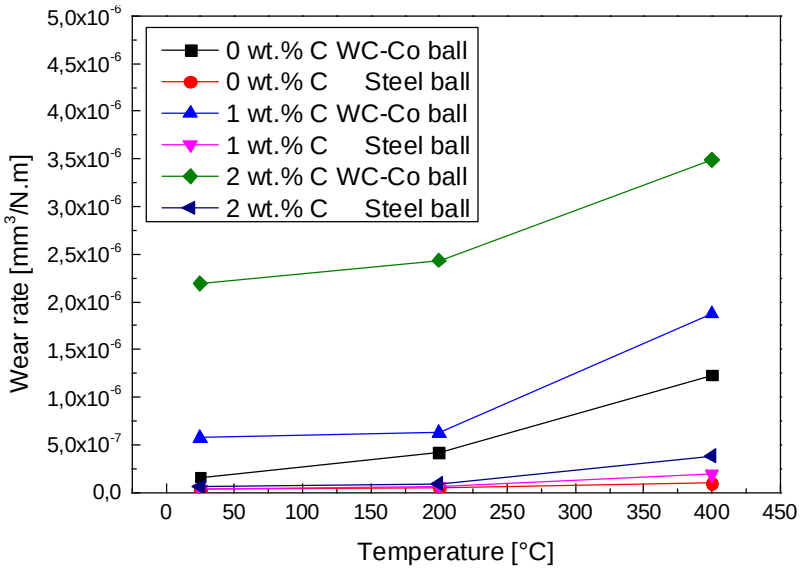

Figure 1 - *specific wear rate of the experimental materials at various temperatures*

#60 The rehabilitation of three centenarian steel bridges

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Abstract This paper follows the other paper presented by BETAR for the Tagus river bridges. It refers to the rehabilitation design projects and undertaken works of three centenarian steel/ iron bridges executed in Portugal and belonging to the national road network, namely Portimãos's Bridge over Arade river next to the coast line, Alcacer's Bridge over Sado river and finally Portela's bridge over Mondego river.

Their typology varies. The three bridges were executed with steel or iron elements with rivets that are connected in trusses. These three examples cover a longitudinal box girder truss-type deck with upper slab and also two different bowstring type of spans. The original platforms were generally made of wood and lately were changed to reinforced concrete slabs to meet traffic necessities. The decks are supported by piers and abutments made of masonry as well as wing walls when existing.

In this paper each bridge is analysed in detail, highlighting its main anomalies which distinguish it situation from the other ones and the purpose of the repair and the reinforcement works that were prescribed.

The existing situation before the intervention is characterized through bridge inspections both principals and special and also through the main conclusions obtained from laboratory tests over samples extracted from precise points of the structures.

The hypotheses for the intervention in order to upgrade each structure to actual regulatory actions are discussed in terms of (i) present restraints, (ii) difficulties of execution due to the lack of resistance of existing materials (for instance non-weldable iron) or particular geometry of the elements or complex connections involving composite members and rivets or even (iii) aesthetics issues regarding patrimonial heritage.

Important factors and curiosities observed during their rehabilitation design and works are also summarized. Namely, the case of the substitution of the concrete slab platform by a larger and special one that is independent from the bridge's superstructure. Or the case of reinforcement of non-ductile structures to the seismic action with displacement control.

The paper ends with a brief conclusion about the major problems that affect this kind of structures though their long existence. The nature of their constitution, the original conceptual design and the influence of its assumptions in the global behaviour of the structures, the difficulty to estimate quantities of repair in the early stages of the intervention (during project-time) where no pickling process has yet started and real deficiencies are covered with paint, the thorough work necessary to add the compulsory resistance preserving its aesthetic and heritage, among other remarks.

#61 Measurement of Residual Stresses in Welded Elements and Structures by Ultrasonic Method

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Abstract. Residual stresses (RS) may change considerably the engineering properties of materials and structural components by affecting their fatigue life, distortion, dimensional stability, corrosion resistance, etc. Although certain progress has been achieved in the development of different experimental techniques, a considerable effort is still required to develop efficient and cost-effective methods of RS analysis. The application of an ultrasonic non-destructive method for RS measurements had shown that, in many cases, this technique is very efficient and allows measuring the RS both in laboratory conditions and in real structures in field for a wide range of materials. Using this technique, one can measure the RS in the same points many times, studying, for instance, the changes of RS under the action of service loading or effectiveness of stress-relieving techniques.

An ultrasonic computerized complex UltraMARS for non-destructive measurement of residual and applied stresses was developed recently. The complex includes a measurement unit with transducers and basic supporting software and an advanced database and an expert system, housed in a laptop, for analysis of the influence of RS on the fatigue life of welded elements. In general, the ultrasonic method allows one to measure the RS in both cases: averaged through thickness or in surface/subsurface layers. The present version of complex allows measuring the averaged through thickness RS in plates 2 - 200 mm thick as well the RS in surface/subsurface layers of material.

The results of RS measurement in standard and large scale welded specimens are presented in this paper. A number of examples of RS measurement in real welded structures are also discussed.

#62 Fatigue Improvement of Welded Joints by Ultrasonic Impact Treatment

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Abstract. The ultrasonic impact treatment (UIT) is relatively new and promising process for fatigue life improvement of welded elements and structures. In most industrial applications this process is known as ultrasonic peening (UP). The beneficial effect of UIT/UP is achieved mainly by relieving of tensile residual stresses and introducing of compressive residual stresses into surface layers of a material. The secondary factors in fatigue improvement by UIT/UP are decreasing of stress concentration in weld toe zones and enhancement of mechanical properties of the surface layers of the material. Fatigue testing of welded specimens showed that UIT/UP is the most efficient improvement treatment as compared with traditional techniques such as grinding, TIG-dressing, heat treatment, hammer peening and application of LTT electrodes. The developed computerized complex for UIT/UP was successfully applied for increasing the fatigue life and corrosion resistance of welded elements, elimination of distortions caused by welding and other technological processes, residual stress relieving, increasing of the hardness of the surface of materials.

The results of fatigue testing of large-scale welded specimens in as-welded condition and after application of UIT/UP are considered in this paper. It is shown that UIT/UP is the most effective and economic technique for increasing of fatigue strength of welded elements in materials of different strength. These results also show a strong tendency of increasing of fatigue strength of welded elements after application of UP with the increase in mechanical properties of the material used. The results of the fatigue testing of welded elements after underwater UIT/UP are also considered.

The results of fatigue testing of large-scale welded specimens show that UIT/UP could be effectively applied for fatigue life improvement during construction, rehabilitation and repair of welded elements /and structures. The areas/industries where the UP process was applied successfully include: Shipbuilding, Railway and Highway Bridges, Construction Equipment, Mining, Automotive, Aerospace.

#63 Acoustic emission crack monitoring in rail track based on synchrosqueezed wavelet transform and Tsallis entropy

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Abstract Crack monitoring of rail tracks aims to identify fatigue cracks in advance, allowing timely repair to be carried out to ensure a smooth and safe operation of the railway system. Acoustic emission (AE) technique is a promising tool for crack monitoring that is highly sensitive to crack growth and able to detect cracks over long distances. Research on rail crack monitoring using AE technique to date is mainly limited to laboratory fatigue tests and small-scale test rigs. However, real rail profile has a strong impact on the propagation features of AE waves; complex crack conditions and high operational noise in the field may significantly reduce the performance of crack detection algorithms. In this context, this paper studies the strategy for AE rail crack monitoring based on a series of field tests with an incipient rolling contact fatigue (RCF) crack.

AE signals were acquired respectively from the cracked rail and the healthy rail with trains running. Synchrosqueezed wavelet transform (SWT) was introduced to explore the time-frequency characteristics of AE signals originating from the rail crack and the rolling noise. SWT could produce clearer wavelet maps than traditional wavelet transform. Here, the optimal mother wavelet was selected by minimizing the Tsallis entropy of wavelet coefficients. The non-extensive Tsallis entropy was adopted instead of the extensive Shannon entropy in order to achieve a better representation of energy distribution of AE signals in the time-frequency domain. The Tsallis synchrosqueezed wavelet entropy (TSWE) was then proposed as an index with time to identify the existence and location of rail cracks in the field. After the key parameters were appropriately determined, the time-TSWE successfully located the incipient RCF crack at 11.7 m away from the sensor with errors less than 0.3 m.

By identifying crack-related AE events from the rolling noise, the time-TSWE is capable of detecting both surface and internal cracks. Although the sensing distance of sensors mounted on the track is relatively short compared to the length of railway lines, the crack monitoring strategy proposed can be applied to critical rail sections with high occurrences of cracks, such as curved sections, turnout areas and transition zones.

#64 Joining TWIP-Steel simulation models

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Abstract JoiningTWIP project aims to support the introduction of TWIP-steels for automotive applications (in cars, trucks and buses) by identifying possible applications and further developing mechanical and low-heat joining technologies to be able to implement multi-material design with TWIP-steels. To guarantee a full view of the project team members from steel industry, car manufacturers, joining technology suppliers and universities are working together.

This work describes the simulation stage of the different technologies. During the project, the materials described in the scope of the project were tested in order to obtain material characterization. Also, the different multi-material joints were tested to describe the joining process and the joining quality. These results will be used to build complex simulation models and prototypes, which show the performance and the behavior of the joining processes of TWIP-steels. Five different technologies were analyzed in the scope of the project: clinching, resistance element, high-speed bolt setting, welding (REW), friction element welding (FEW) and flow drill screwing (FDS). To guarantee the performance of the simulation models, the results were compared to the sampled joint and processes. An optimization process of the different technologies was applied to improve the quality and the performance of the different joints.

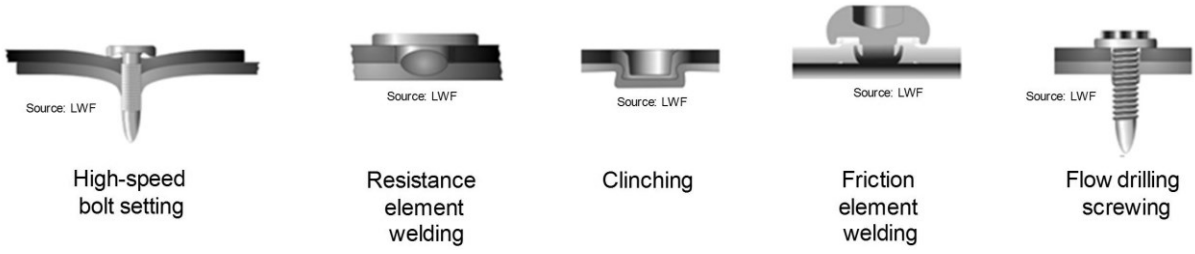

***Figure 1** – Technologies described in the JoiningTWIP project*

#65 Effects of process parameters on physical properties of warm sprayed aluminum and titanium coatings

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[2]*National Institute for Materials Science, High Temperature Materials Unit, Tsukuba, Japan*

Abstract Warm spray, originally invented and implemented in the National Institute for Materials Science (Japan), is a novel thermal spray technique that allows forming dense and pure metallic coatings. It is capable of controlling the temperature of the propellant gas by diluting the combustion flame with an inert gas such as nitrogen, which is injected into the mixing chamber situated between the combustion chamber and the powder feed ports. Since the temperature of the propellant gas can be controlled from ~700 to 2,000 K, powder particles can be softened without significant oxidation before impacting onto the substrate.

Two series of coatings, i.e., Al and Ti, were prepared with various nitrogen flow rates in this study. There were visible effects of the selected warm spray parameters on several physical properties of the Al and Ti surfaces and their morphology, since warm spray parameters have an influence on the temperature of the deposited particles. At first, the angle of wetting via polar water and non-polar diiodomethane was measured. Based on these results, surface free energy (SFE) was calculated for each sample. Additionally, the SFE values were correlated with the roughness of the surfaces and its morphological properties. Moreover, an attempt to find a correlation between the determined physical properties of the coating surfaces and adhesion properties and corrosion resistance in salt spray corrosion test (SSCT) was made.

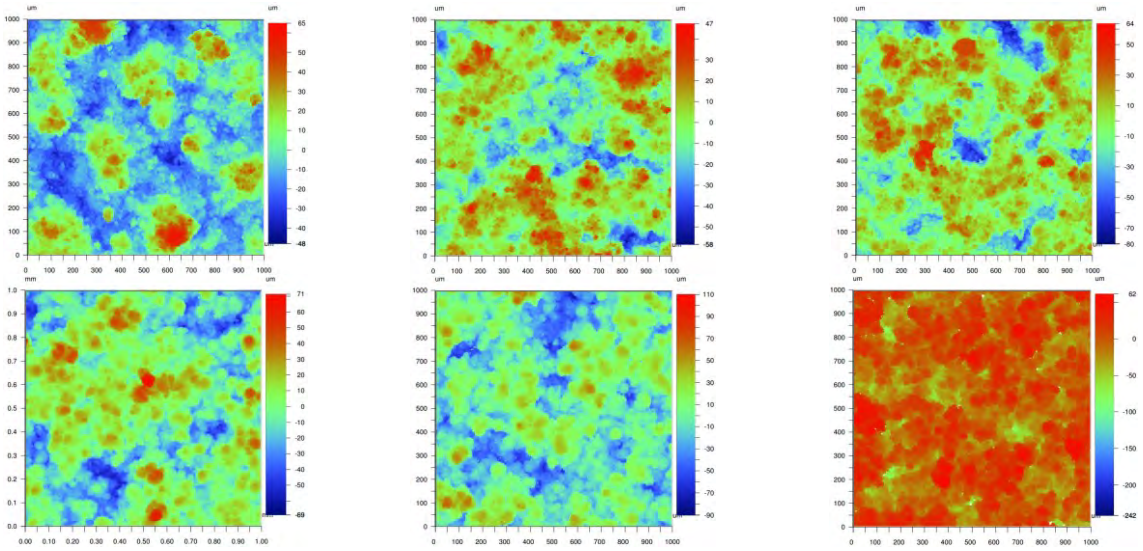

Figure 1 *– Two-dimensional visualization of Ti (upper row) and Al (lower row) coatings deposited using different warm spraying parameters obtained by an optical profilometer*

#66 Fatigue Behavior of Tailored Blank Thermoplastic Composites with Internal Ply-Drops

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Abstract The technology of tailored blanks is used for thickness variation within a laminate plate to reduce weight in areas with a lower load. Ply-drops are used for the thickness variation and their effect on fatigue characteristics has not yet been investigated for the thermoplastic matrix. This paper describes experimental investigation of asymmetrically tapered carbon fibre-reinforced thermoplastic specimens cyclically loaded in tension. The specimens were manufactured according to design features of a rib demonstrator used in an aerospace structure. Two transitions were investigated: from 16 to 13 and from 13 to 11 layers. The investigated effect of specimen edge quality (water jet cutting and milling) caused the change of fatigue life by 25%. In case of the run-out specimens with more than 3 million cycles an early failure occurred at higher load levels as due to a damage accumulation. Value of E-modulus was not changing during fatigue loading. Fractographic examination using scanning electron microscopy confirmed occurrence of various features typical for the ply-drop failure. It was shown that laminate edges of ply-drop integrated structures should be machined precisely in order to maintain their durability.

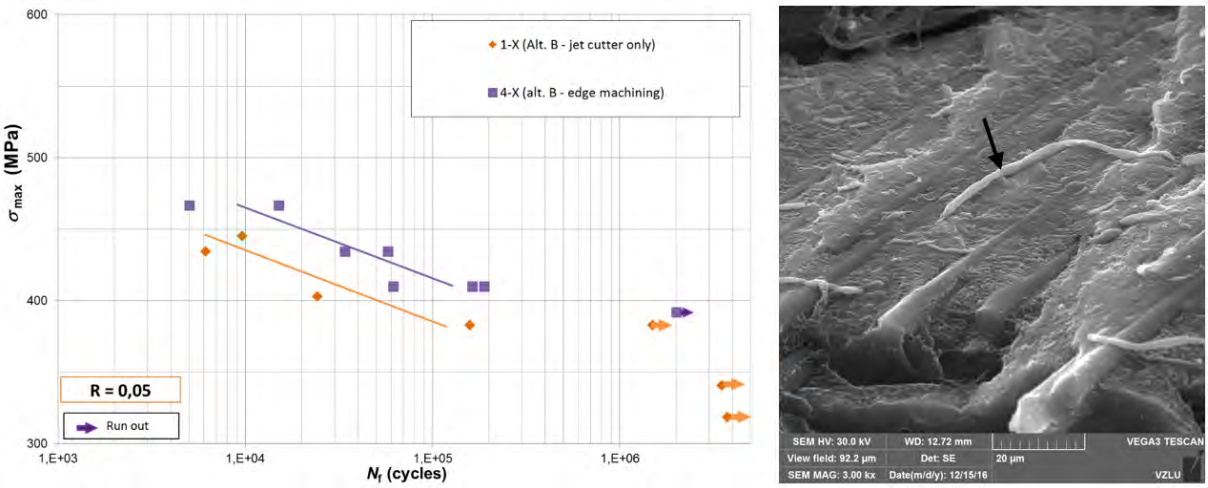

***Figure 1** – Effect of specimen edge machining on fatigue life (left) and rollers typical for mode II fatigue loading observed on ply-drop fracture surface (right).*

#67 Assessment of deposited on internal pipe surface corrosion protective layers behavior in DIC assisted mechanical tests

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Abstract Limited amount of natural resources stimulates research in the non-conventional mining technology field. One of perspective sources of natural gas are shale rocks. Hydraulic fracturing is usually utilized for shale gas mining but is controversial from the environment protection point of view. An alternative way of shale gas extraction is liquid/supercritical CO_2 usage; however, corrosion problems in moist medium must be considered, especially when other impurities are present in pipeline. Pipes produced according to petroleum industry standards, usually made of carbon steels, might be protected by anticorrosion coatings deposition, nonetheless mechanical properties of base material and new layer have to be known, as well as interface strength and behavior during loading. Determination of mechanical properties changes after protective layer deposition may be done with mini-samples based testing. The paper presents methodology and results of 3-point bending tests of miniaturized samples made of base material and base material - protective layer systems. Static and dynamic mechanical tests were assisted with Digital Image Correlation (DIC) measurements allowing to obtain strain distribution maps. Detailed analyzes of these maps for Inconel 625 and stainless steel protective layers has been done leading to conclusions concerning deposited layer quality and cohesion. Results of DIC assisted mechanical testing were supplemented with SEM observations of layers' cross sections, fractures and micro CT scans.

Acknowledgements: The Project is financed by The National Centre for Research and Development within Blue Gas II Programme, Contract no. BG2/DIOX4SHELL/14

#69 Influences of surface morphology of fatigue behavior of metastable austenitic steel AISI 347 at ambient and 300 °C

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Abstract According to their excellent mechanical and technological properties as well as their corrosion resistance austenitic stainless steels are used to manufacture components in nuclear power and chemical plants. After quenching from solution annealing temperature, a large number of technically relevant chromium-nickel stainless steels exhibit austenite in a metastable state. Due to plastic deformation in these alloys local phase transformations from paramagnetic austenite into ferromagnetic martensite occur which can affect the usability of the material in a positive manner. Customarily, pipes in nuclear power plants are roughly polished; however a few zones in the pipes might be grounded, which significantly influences the surface morphology and consequently the fatigue behavior of this materials [1]. Using a new low temperature turning process with carbon dioxide cooling in the cutting zone a variation of the morphology at the specimen surfaces can be realized [2].

In this contribution, the influences of cryogenic turning processes of metastable austenitic steel AISI 347 (X6CrNiNb1810) on fatigue behavior was investigated in stress-controlled fatigue tests at ambient and 300 °C in air. The surface morphology is defined by distribution of three phases (i) austenite, (ii) alpha´-martensite and (iii) epsilon-martensite, surface roughness and residual stresses. Additionally, a near surface nano-crystalline microstructure with the max. depth of 5 µm was found. For the intensive characterization of the surface and near surface morphology investigations using x-ray diffraction and scanning electron microscopy including focus ion beam preparations were performed. The cyclic deformation behavior was characterized by stress-strain hysteresis measurement. An additional magnetic measurement allows the characterization of the phase transformation from paramagnetic austenite in ferromagnetic aplha´-martensite.

[1] T. Poulaina, J. Mendeza, G. Henaff, L. De Baglion, *Characterization of damage during low cycle fatigue of a 304L austenitic stainless steel as a function of environment (air, PWR environment) and surface finish (polished, groun*d), Procedia Engineering 160 (2016) 123-130

[2] J.-C. Aurich, P. Mayer, B. Kirsch, D. Eifler, M. Smaga, R. Skorupski, *Characterization of deformation induced surface hardening during cryogenic turning of AISI 347,* CIRP Annals - Manufacturing Technology 63 (2014) 65-68

Acknowledgements

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#71 Stress state analysis and optimization in the vicinity of the sensor of SMART-material

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Abstract Composite materials in practical human activity are well positioned, and their range of applications is constantly expanding. Composite materials based on polymer are widely used among the different kinds of composite materials. The nomenclature of these materials is very wide and their properties are different from each other. For these reasons, the complex structure of the material and number of other factors, the traditional methods of assessing the strength and reliability of construstions from polymeric composite materials (PCM) should be complemented. In particular, by using new and effective monitoring systems. One of these modern methods of diagnostics is creation SMART-materials with embedded sensors. As a sensors the piezoelectric sensors or optical fibers are used. They can be located on the surface of the material or embedded in the polymer composite material. New methods of diagnostics products from these materials increase their competitiveness.

Based on numerical modelling and experimental researches, the aim of the work is to search different ways of solving the problem, that allow to increase SMART-material reliability as well as proper registration of the strain field, using the fiber-optic sensors and piezoelectric elements.

The problems of the glue compound geometry optimization that appear while gluing sensitive elements on the PCM surface and designing optical fiber outputs were considered in this paper. The results of glue compound influence on sensors indications were shown. Besides, the stress-strain state analysis that includes the singular solutions for the points, where infinite stress may occur, was carried out in the framework of this study.

#72 Micro and macro mechanical analysis of gas pipeline steel

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Abstract Pipelines of gas transportation networks are exposed to aggressive chemical reactions and to demanding working conditions. The actual safety margins of these infrastructures depend on a number of factors that include the internal gas pressure, the external actions, the environmental characteristics and the material properties, which evolve with time. The aging of these structural components increases the risk of failure, with significant economic losses and severe environmental consequences. Monitoring during operation of pipelines includes visual inspections and ultrasonic measurements, which are periodically performed to detect the possible formation and propagation of localized damages. Distributed material degradation is instead evidenced by the mechanical testing of material samples extracted from the pipe wall. The experiments are usually carried out according to standardized procedures, which are rather time consuming and expensive. However, structural diagnosis can rely on fast and cheap non-destructive approaches, which are potentially applicable also in this context. In particular, different mechanical characterization methodologies based on indentation techniques can be considered. The tests can be performed at different scales, seeking for the best compromise between the maneuverability of the experimental equipment and the transferability of the laboratory results to the field conditions. In fact, the overall aim of the present investigation is the development of effective structural diagnosis procedures based on in-situ measurements. The proposed alternatives are comparatively assessed on pipeline steels of different compositions and in different states: as received, mechanically hardened, thermally treated and chemically degraded.

#73 Electrical management of the PEO process of Al to produce hard and thick alumina protective coatings

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Abstract The Plasma Electrolytic Oxidation (PEO) is an electrochemical process to produce protective oxide coatings on light-weight metals (Al, Mg) which are of increasing use in aeronautic and automotive industries. Growth of the oxide layer takes place at potentials above the dielectric breakdown voltage of the insulating oxide layer leading to the development of numerous short-lived micro-plasma (or micro-discharges) over the processed surface. The resulting coating exhibits improved surface performances in terms of wear protection and corrosion resistance promoted by high-temperature crystalline phases such as α-alumina.

If by the past the use of AC current to supply the electrodes allows significant improvement in the final oxide properties control (instead of DC current), it remains that the use of a pulsed bipolar (PB) current provides more opportunities to manage the PEO process, specifically in terms of energy saving. By using a PB current for which the waveform parameters can be adjusted in a wide range, the aim of the present communication is to give an overview of recent achievements into the influence of some electrical parameters on the efficiency of the PEO of aluminum. A particular attention was paid to the charge quantity of the anodic half-period versus the cathodic one, the anodic current density and the current pulse frequency.

Correlations are established between the micro-plasma characteristics (density, lifetime, size) determined by fast video imaging (>125kfr/s), the light emission detected using a photomultiplier (9 ns time resolution) and the elaborated oxide coatings (thickness, roughness, hardness and α-alumina content). It will be shown that the best protective layers in terms of hardness (> 1400Hv), growth kinetic (> 100µm/h), α-Al_2O_3 content (≈ 35 %vol.) have been achieved using an asymmetric PB current combined with an high anodic current density (80A.dm^{-2}) and an high pulsed frequency (900Hz). Within these specific electrical conditions, detrimental effects of numerous, large-size and long-lived micro-plasma on the growing oxide layer are minimized.

#74 Microstructure and mechanical properties of iron produced at different temperatures via Impact Sintering method

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Abstract Iron is a constituent of many modern materials, including the strongest ones. Iron based alloys may by produced by means of various methods, with Impact Sintering among others. High compaction pressure level accompanied with the large shear deformation allows to obtain high density and strength samples at lowered temperature in comparison to the traditional powder metallurgy methods.
Two Fe powder types of different grain size, shape and purity were used for samples production. Coarser powder denoted as P has average grain size in the range of 50-150 μm and contained Mn, Cr, P, S, Si, Ca impurities. Powder denoted as D was finer, with average grain size in the range of 3-10 μm, and was made of technically pure iron. Consolidation process was carried out in the 500 -1100 °C. Final products have shape of disks with 25–27 mm diameter and 9–10 mm height.
The samples produced at temperature above 700°C revealed high density approaching the level for bulk Fe, which is the evidence on high quality compaction resulted from impact sintering. The highest value of hardness was measured for the samples sintered at the lowest temperature (500-700°C). It was caused by finer microstructure. No significant grain size growth has been observed for P powder compacted at the temperatures below 900°C.
Tensile test and small punch test (SPT) were chosen for mechanical properties determination. The mini-samples of 5 mm gage section length were used for the tensile tests. SPT tests were carried out on the samples of 8 mm diameter and varied thickness in 0.45 – 0.65 mm range. The maximum loading force during SPT test was registered for samples sintered at 600°C, but the highest deflection, about 2 mm exhibited disks produced at 1100°C.

Fig 1 presents fracture surface of samples after tensile test. Necking phenomena of the specimen might be observed. Dimpling and rough surface typical for ductile fractures were revealed, which confirmed high plasticity of manufactured sinters

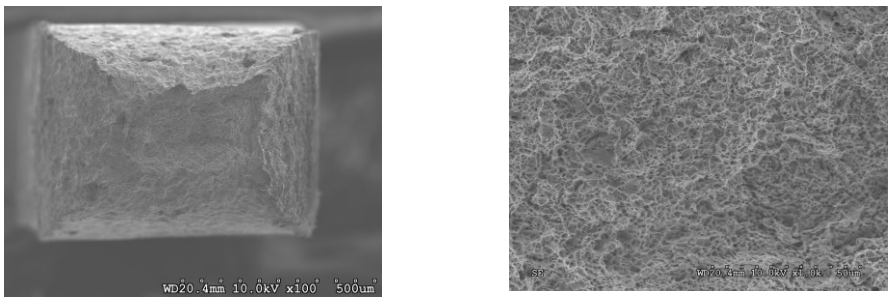

Fig. 1. Exemplary fracture surface of iron sintered via Impact Sintering method

The work was financed by Polish National Science Centre, the Contract no UMO-2014/15/N/ST8/03388.

#75 Potentiality of SHM and PFA for a new design approach of low weight aircraft structures

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Abstract The object of this work is to show the potentiality of the application of SHM (Structural Health Monitoring) systems and PFA (Progressive Failure Analysis) methodology, from the beginning of the design phase of wing box composite stiffened panels, for obtaining lighter structures respect to the current ones. The common industrial approach to satisfy the certification requirements (EASA AMC 20-29) for composite structures, based mainly on the application of high conservative knockdown factors to the material strength properties and/or performing extensive test campaigns, can lead to oversized structures and to an increase in costs and timing. The use of information coming from SHM systems and of the PFA methodology could exploit the full potential of damaged composite materials in favor of a greater weight reduction. By detecting the damages thanks to SHM systems, the structure could be designed with higher design allowables (more reliable detection of BVID – Barely Visible Impact Damage) improving the static strength for a reduced damage size detection.

Two aircraft wing box composite stiffened panels have been preliminary designed under static compressive load, one at the wing root and the other one at the wing tip, according to the traditional industrial design approach. Then, they have been re-designed releasing some of the current conservative criteria, because they were considered resolved by SHM systems: no BVID knockdown factor, no notch material design allowables (only bonded joints and bonded repair are considered) have been applied. The new design has shown the potential weight reduction achievable, the design parameters and panel subparts to which the panel weight is more sensitive. The results of these analyses provide fundamental requirements for the SHM system definition in terms of "where to monitor and why".

Successively, in order to exploit the actual residual strength of impact damaged panels, also PFA has been performed on stiffened panels considering a discrete damage model against the traditional design approach; the latter, based on the first ply failure design criteria and assuming the structure uniformly damaged by using reduced design allowable obtained at coupon level. The results show that a significant weight reduction is potentially achievable by using PFA, and the potentiality of this methodology as a valid design tool to investigate a new design philosophy based on the evaluation of the residual strength of panels with discrete damages.

#77 Numerical simulation of residual stresses induced by TIG butt-welding of thin plates made of AISI 316L stainless steel

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Abstract The paper herein presented refers to the numerical simulations of a TIG butt-welding process applied to thin plates made of an AISI 316L austenitic stainless steel. Finite element (FE) thermal analyses were initially carried out in order to obtain the transient temperature distributions in the plates, and, subsequently time-dependent thermal results were used in the FE structural analyses, in order to calculate the residual stresses and deformations introduced by the welding process. A double Gaussian distribution – namely a double ellipsoid -, with front and rear dimension's areas of the arc defined based on real weld bead's measurement, was used as the heat source model (power density), and it was considered that it moved at constant speed. Numerical results calculated were in good agreement with the experimental residual stresses measured by the hole-drilling method, showing the adequacy of the method implemented and its potential to estimate residual stresses and distortions. In fact, it was found a deviation of 19 % for the maximum principal stress calculated, while for the minimum principal stress a deviation value of 9 % was obtained; in addition, the simulated weld bead presented slight deviations from the macrograph sample and the differences related to the depth of the weld pool were around 2%.

#78 Structural integrity analyses of two gas turbine's exhaust systems used for naval propulsion

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Abstract Heating and cooling cycles, as well as accelerations and decelerations, to which naval gas turbine's exhaust systems under study are submitted to, could lead to the nucleation and propagation of cracks, and result in the reduction of its expected fatigue life.

The paper herein presented refers to the numerical simulations of the mechanical and thermal behaviours of two different gas turbine's exhaust systems used for naval propulsion. In addition, some experimental values that were collected, namely temperature and pressure, served as input values for the finite element analyses carried out.

The analyses made to the exhaust systems revealed the existence of high stresses near the lower support flanges, which are mainly caused by the non-uniform thermal expansion that the exhaust systems are subjected to. Additionally, redesigned exhaust systems were studied and the use of two alternative materials was assessed, in order to enhance the thermal behaviour of the exhaust systems and, therefore, increasing its fatigue life.

The modifications introduced in the exhaust systems resulted in the reduction of the induced stresses. However, frequent surveys should be performed to the critical welds of the exhaust systems, in order to prevent crack propagation from the weld toes. Moreover, high quality fabrication is required in order to avoid the presence of initial defects in the structure.

#79 Thermal barrier coating thickness estimation by infrared thermography using neural networks optimized by genetic algorithms and principal component analysis

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Abstract We used artificial neural networks to process laser infrared thermography data in order to evaluate thermal barrier coating thicknesses. We present a new method for training the neural network with data pre-processing by principal component analysis to optimize the network input number and the genetic algorithm for determining optimum initial weights for the network training carried out by the back-propagation algorithm. The two algorithms performances' recombination made it possible to reduce the calculation time and to estimate thicknesses with deviations less than 5%.

Keywords Thermal barrier coating thicknesses, pulsed laser infrared thermography, artificial neural networks, genetic algorithms, principal component analysis, finite element method.

#81 Brittle Fracture Modeling for Steel Structures operated in the Extreme

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Abstract The Extreme here is an environment that contains conditions that are hard to survive even for steel structures due to extreme temperature, corrosion, inappropriate service and repair. So not only the mechanical properties and behavior of steel structures are important for structural integrity but also the phase transition processes, inhomogeneity and uncertainty factors. These problems are observed and discussed in the paper consisting of three main theoretical parts: the multiscale modeling approach for structural damage accumulation, the theory of low-temperature brittle-ductile transition for bcc steels, and uncertainty factors estimation concept. The applications describe the locomotive tire lifetime estimation at low temperature conditions, weld inhomogeneity calculation and bridge service life prediction. The modeling approach based on Kachanov-Rabotnov structural damage accumulation theory and stochastic crack growth modeling. Bayesian probability approach has been used for uncertainty factor estimation. The experimental research included the internal friction study of bcc steel, the mechanical tension and impact toughness testing for probes prepared from used in climatic condition of Central Yakutia locomotive tire steel, the low-cycling testing for welded steel probes, and microhardness estimation. The inhomogeneity of probes used for stress and strain state modeling. The microstructural study reveals the small cracks in heat affected zone so the size and distance between such defects used for stochastic modeling visualization of crack propagation and crack velocity estimation. The concept of service life estimation for welded steel bearing for bridges has been presented.

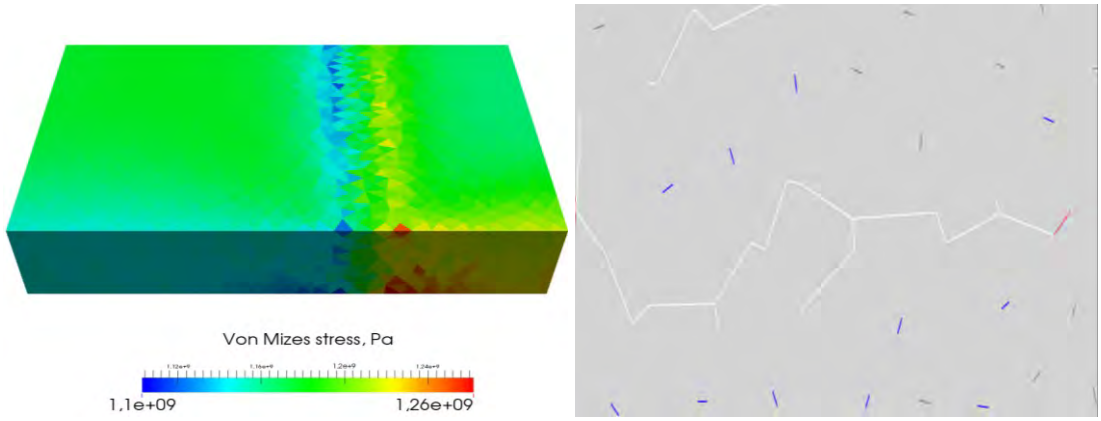

***Figure 1** – Results of numerical modeling of (a) stress distribution and (b) crack propagation in heat affected zone for low-cycled welded steel probe.*

#82 Lock-In Thermographic Stress Analysis of notched and unnotched specimen under alternating loads

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Abstract

Thermo-elastic Stress Analysis (TSA) is a contact free infrared imaging method to measure stress fields. In fatigue experiment with alternating loads, the elastic effects are connected with the loading frequency. The Lock-In TSA uses this connection to reduce noise and other bothering effects by relying on the loading frequency (fundamental frequency) and depending higher multiple of the loading frequency (higher harmonic frequencies) by filtering with a discrete Fourier transformation (dft). This filtering leads to a spectrum of temperature amplitudes and phases. The local stress is computed out of these spectrum via the thermo-elastic effect mentioned by Lord Thomson [1].The higher modes can be referred to dissipative effects [2]. The phases describe the shifting between the loading maximum and the local stress maximum.

The TSA measurements requires local adiabatic conditions and these depend from the dimension of the loading frequency and the existing local gradients. Furthermore, thermographic measurements depend on the quality of the surface emissivity. The coating of the specimen, its thickness and uniformity influence the results of the TSA.

To evaluate the influence factors frequency, load level, local gradients, firstly experiments with unnotched specimen were carried out to calibrate the measurement method. To determine the elastic stress fields and the dissipated energies at notches with different notch depths and propagating cracks were examined. The experiments showed that the local maximum stress at the notch measured by TSA increases with the loading frequency and tends to a boundary value. This indicates that the TSA is influenced by the heat flow in the material. That limits the applicability of the TSA for measuring stresses at cracks and notches in fatigue experiments. For accurate measurements, a correction depending on the loading frequency has to be applied.

Lock-In TSA-measurements on notched and cracked specimen showed, that the maximum stress in front of crack is lower than the maximum stress in front of a notch with an equivalent length. In case of the notched specimen, dissipative effects are only observable close to the notch. In the cracked specimen the dissipative effects exhibit higher values and reach further out into the specimen. Summarizing the elastic and dissipative amplitudes, no significant differences between notched and cracked specimen are visible.

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#83 Experimental investigation of short crack growth at notches in 7475-T761

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Abstract

The lifetime of cyclic loaded components is generally divided into two stages: crack initiation and crack propagation that begins at a technical crack length. Following this division, the crack initiation lifetime is about 70-80 % of the total lifetime, depending on the defined technical crack length.

However, investigations performed on technical alloys have shown that cracks are initiated after only a few cycles and consequently the major part of the cyclic lifetime is covered by the propagation of short fatigue cracks. Hence the propagation of short cracks has to be investigated in detail to obtain realistic lifetime predictions.

Fatigue experiments were performed on Single Edge Notched specimens in a special equipped testing machine with fixed grips to minimize bending forces. For crack length measurement a high-resolution potential drop method was used. The data of the potential drop measurement were smoothed using a LOESS-algorithm (robust locally weighted regression). Due to the smoothed graph of the potential drop data, cracks with a length of less than 150 microns could be detected. The crack initiation lifetime was found to be less than 20 % of the total lifetime.

These measurements as well as additional FEM calculations have shown that the geometry of the small cracks significantly influences the potential drop. This leads to a consideration of the crack initiation site as well as the crack front geometry in case of a model-based determination of the extent of small cracks.

To evaluate the early stages of crack propagation and to verify the crack shape obtained in previous fatigue tests with single overloads, a detailed analysis of the two-dimensional short crack propagation on the specimen surface was conducted. Therefore, the length of quarter elliptical corner cracks was determined on the specimen sides and in the notch root after defined fatigue intervals.

The results of this investigation combined with some simple simulations of the two-dimensional crack propagation showed that the propagation of short cracks in both surface directions is interdependent and that thereby the crack prolongation along the notch root is dominant.

The crack propagation in the notch root is controlled by the notch stress concentration and the crack prolongation on the sides of a specimen is effected by the crack propagation in the notch root. In return, the crack propagation on the specimen surface (long crack propagation direction) leads to a reduction of the crack propagation rate in the notch root. This interdependence of crack propagation directions will be the basis for a new crack propagation model to predict the cyclic lifetime of notched components.

#85 Homogenization Method for Composite Structures with Relieved Periodicity in the Thickness Direction

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Abstract This paper aims to develop a novel asymptotic expansion homogenization and localization analysis for advanced composite structures by relieving the periodicity in the thickness direction. Introduction of relieved periodicity is an enhanced approach in homogenization and localization method whereby the years developed method usually implements the periodicity in three directions, i.e. in-plane and out-of-plane directions. This means that the representative volume element (i.e. unit-cell) is assumed to be infinitely repeated in those three directions. However, composite laminates, especially for aerospace application, are very thin. In addition, several types of composites, e.g. 3-D composites and sandwich honeycomb composites, do not possess repeating pattern in the thickness direction. The analysis of such kinds of composites necessitates a model which represents the whole thickness of unit-cell (i.e. finite thickness unit-cell model). Correspondingly, the periodicity in both in-plane directions is of considered, while that of the thickness direction is relieved. The formulation is rigorously developed in asymptotic expansion, and it is numerically implemented by an in-house code, and applicable for general composites structures.

Figure 1 shows the configuration of analyzed honeycomb sandwich plate with Al core and CFRP face, which is given temperature chang of -120°C, and the thermal residual stress distribution of σ_{11} are also indicated. The result "FEM" is obtained by analyzing large plate and picked up that of the center cell. "Standard" and "Present" are obtained by the homogenization method, where "Standard" is usual one and "Present" is by relived periodicity in the thickness direction. "Standard" shows the strong constraint in the thickness direction, on the other hand "Present" is very similar to "FEM" which is under the actual boundary condition. Thus it is proved that the present method is very accurate and effective.

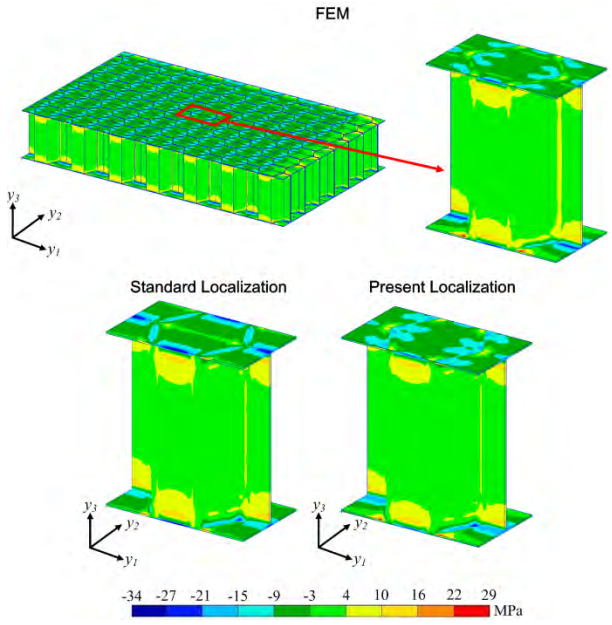

***Figure 1** – Honeycomb sandwich plate with CFRP face under T=-Δ120°C*

#86 Fatigue crack monitoring using plastic optical fibre sensor

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Abstract Optical fibre sensors have shown their excellent potential as one type of important sensors for damage detection and structural health monitoring. This paper discussed the feasibility of real-time monitoring of fatigue crack using a novel extrinsic plastic optical fibre sensor. This intensity-based optical fibre sensor was fabricated by connecting two cleaved optical fibres into a capillary tube and inserting some infilling into the tube to improve the sensitivity of the sensor. Aim of this sensor is to detect crack initiation and subsequently monitor the propagation of crack under fatigue load, relying only on plastic fibre sensor and a relatively simple signal processing method. Thus, the monitoring system can be composed of inexpensive components and easily conducted. To validate the proposed sensor and monitoring method, specimens are subjected to harmonic fatigue loading in order to induce stable crack propagation. Performance of the fabricated IPOFs sensor was evaluated by comparison with two other techniques. Namely, crack opening displacement (COD) gauge and acoustic emission (AE) were used for the purpose of calibration and comparison. The results show remarkable resemblance in terms of crack initiation and propagation identification exhibited by all three types of sensors, highlighting the potential of proposed sensor for crack initiation detection and subsequent monitoring of crack propagation.

#87 Role of the ultrasonic shot peening on fatigue behavior of 316L machined samples

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Abstract The surface represents a sensitive zone subject to particular conditions like high stress loading, friction or ambient atmosphere. In order to enhance the part integrity, mechanical treatments focused on the surface have been developed such as deep rolling or air-blast shot peening. Among them, the Ultrasonic Shot Peening (USP), also found as SMAT in the literature, generates surface severe plastic deformation by numerous colliding shots having random impact trajectories.

This process was used to superficially deform a 316L austenitic stainless steel at room temperature. An industrial surface state, machined and mechanically polished, was intentionally selected in order to characterize the modifications induced by USP on rough surfaces. The analyses were conducted in terms of surface integrity, microstructural characterization and mechanical behavior. The overall mechanical properties were enhanced by the USP treatment increasing the yield limit and the fatigue strength. However, the USP treatment increased the global roughness. The effect of tool marks generated during machining on the initiation and propagation of secondary cracks will be discussed.

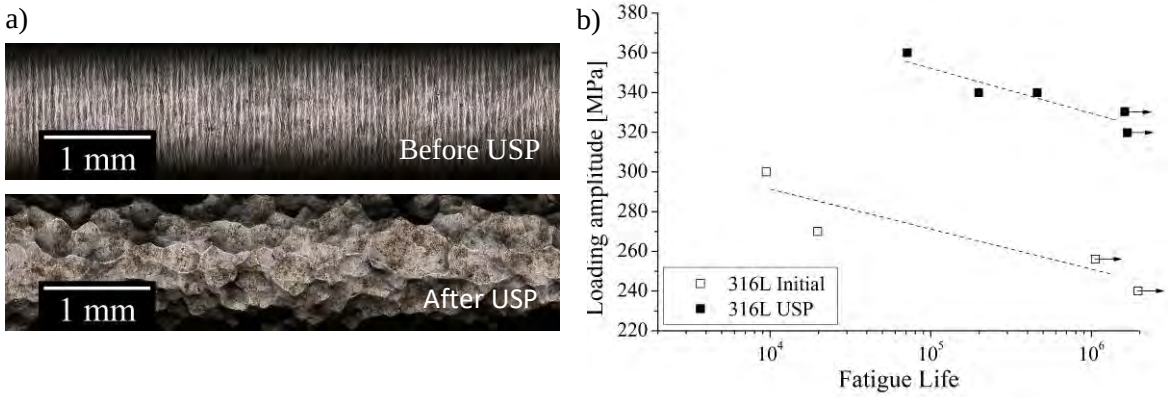

***Figure 1** – a) specimen surface states before/after USP and b) fatigue life as a function of the stress amplitude for both conditions*

#88 Fatigue damage analysis of the wing-fuselage attachment lug

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Abstract Aeronautical structures can realize their complex stationary and moving operational duties through a lug-type joint. Under cyclic loading, such a load transfer assembly represents zone in which the combination of the stress concentration, fretting and corrosion can lead to the crack initiation and the crack growth at hole of the lug. The fatigue cracks initiated in such position may be approximated either by through-the-thickness or surface cracks (quarter-elliptical or semi-elliptical crack). In this context, a design of lug-type joint against fatigue is one of the critical issues to prevent the failure during the operation. Therefore, the fatigue life assessment is significantly important to ensure the safety and reliability of aeronautical components.

In the present paper a computational fracture mechanics based model is proposed for the fatigue damage analysis of a wing-fuselage attachment lug with quarter-elliptical corner crack emanating from a hole. The crack growth behaviour is examined through the following issues: stress analysis, residual life estimation and crack path evolution. The stress field and the stress intensity factor are computed by employing analytical and numerical approaches. In order to assess the fatigue life to failure for both, depth and surface directions, the stress-dependence crack growth model is applied. Further, such crack growth concept is taken into account to simulate the crack path of a quarter-elliptical corner crack. The predictive capability of proposed computational model is verified by using experimental crack growth data. The comparison between different calcuations and experimental observations shows good correlation. Therefore, the crack growth model proposed in this study can be employed for the fatigue strength assessment of the wing-fuselage connection with a quarter-elliptical corner crack either in the design phase to select optimal geometry-material parameters or during exploatation to enable timely prediction and avert of sudden failure under cyclic loading.

Keywords: Fatigue, quarter-elliptical corner crack, attachment lug, residual life, crack path.

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#89 Investigation of Aggregate Size Effects On the Compressive Behavior of Concrete By Electromechanical and Mechanical Impedance Spectroscopy

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Abstract Concrete is a composite material that is composed of cement mortar and aggregate. The grades of aggregates in the internal structure of concrete affect the mechanical properties of concrete and its compressive strength. In this study, in order to investigate the effect of the grade of aggregates on the compressive strength of concrete cubes in age of 28 days, three-dimensional concrete models are created by idealizing the material properties such as modulus of elasticity and mass density which were experimentally acquired. Piezoelectric wafer active sensors (PWAS) are embedded in the core of the concrete cube models with aggregates in fine, medium and coarse sizes and the harmonic analyses are simulated in a commercial software, ABAQUS® using the multiphysics finite element method (MP-FEA). Eventually, electromechanical impedance spectroscopy (EMIS) results as well as mechanical impedance spectroscopy (MIS) results are obtained to highlight the relative change in the impedance results depending upon the aggregate size. Thus, EMIS and MIS simulation results are employed in order to predict the effects of the aggregate grade on the compressive strengths of the concrete models.

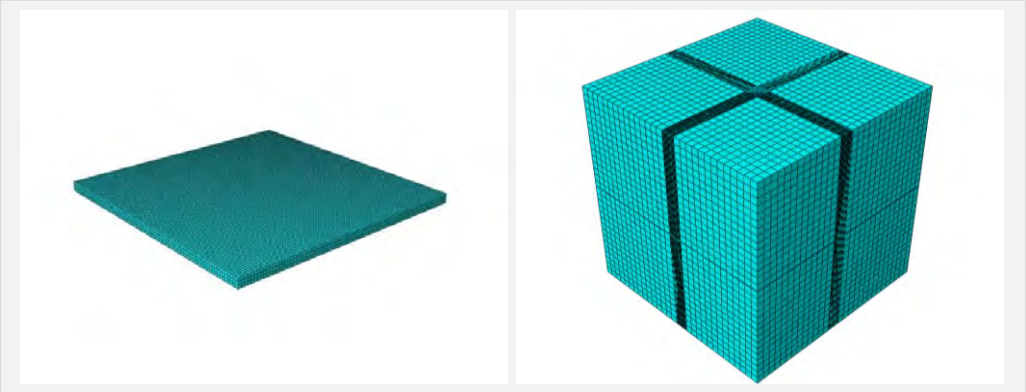

Figure 1 - *PWAS and embedded PWAS-Concrete model*

#90 Simplified Assessment of the Effects of Columns Shortening on the Response of Tall Concrete Buildings

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Abstract The constructive process as well as the time-dependent effects must be considered in the assessment of the response of complex concrete structures. For tall buildings, the adequate prediction of vertical elements shortening is required to determine its effects on other structural and nonstructural elements, usually overestimated by linear elastic analysis. Thus, simple numerical methods which make it possible to consider the most relevant aspects of the structural behaviour may be useful in the early stages of a project. In the research presented herein a simplified method, which considers the viscoelasticity of concrete as well as the construction sequence, was used. Its adequacy was assessed by comparison of the results for a tall concrete building with those obtained with a commercial software which incorporates a nonlinear staged construction analysis package. The good correlation between the obtained results indicates that the simplified method used may be applied to help make appropriate design choices.

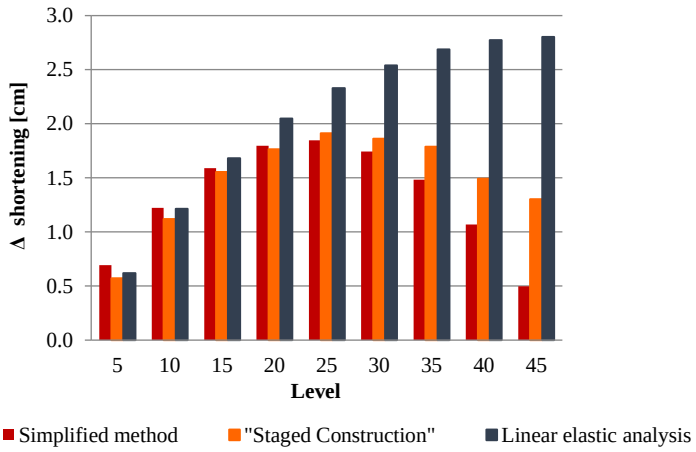

***Figure 1** – Differential shortening values at 30 years after the construction of the building*

#91 Influence of the SMA Constitutive Model on the Response of Structures

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Abstract Strong earthquakes may impose significant displacements in structures, which can result in excessive displacements at structural joints. Previous numerical studies have shown that the recentring capability of shape memory alloys (SMA) can be applied to limit joint openings and maximum longitudinal displacements. However, these studies do not focus on the influence of the SMA constitutive model adopted on the estimated displacements. A sensitivity analysis was performed using simplified two-degree-of-freedom models, which represent two-frame reinforced concrete bridges with various ratios of natural periods of vibration, connected by SMA bars. These models were implemented in a MATLAB based program for nonlinear dynamic analysis. The obtained results show that the relative displacements are more sensitive to the SMA model than the absolute displacements.

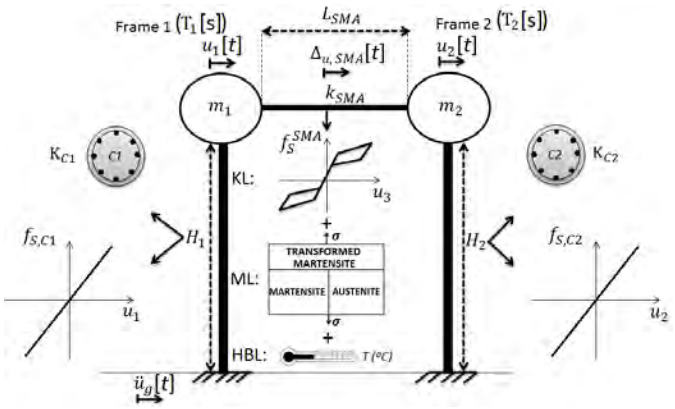

***Figure 1** – Two-degree-of-freedom model used in the sensitivity analysis*

#92 Synthesis of experimental testing and fatigue behavior of laser stake-welded T-joints on medium-high cycle fatigue range

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Abstract The paper presents a synthesis of experimental fatigue tests and theoretical study of laser stake-welded T-joints. The focus is on the influence of crack tip plasticity on fatigue behavior when the joints are loaded under tension and bending. Laser stake-welded T-joints are currently employed in sandwich panels to achieve weight reduction e.g. in shipbuilding. In view of the application of those structures in load-carrying situations, the fatigue assessment of the joints is crucial and challenging. The study presents experimental results of sandwich-panel specimens made of laser stake-welded joints. The load ratio R was kept constant and equal to 0. Number of cycles to failure was taken when the face and web plates at the critical panel joint were separated during final fracture. Finite Element (FE) analyses of the considered panels were carried out, and the experimental data were synthesized by means of the J-integral approach. Fatigue curves based on $\sqrt{J}$ were presented for tension and bending (see Fig. 1-a).

The results showed that the slope of the fatigue curve is different when the joints are loaded under bending or tension (see Fig. 1-a). This difference in the slope was mainly due to different stress gradient at the crack tip. Based on these findings, further investigation of the stress gradient at crack tip and of the crack tip plasticity has been carried out (see Fig. 1-b). Utilizing the first order plastic radius defined by Irwin, a new method is proposed that permits the number of cycles to failure under bending to be derived directly from the tension fatigue curve, employing an effective J-integral. The method has been later verified against a case study selected from the experimental tests. It showed a good estimation of the number of cycles for failure under bending.

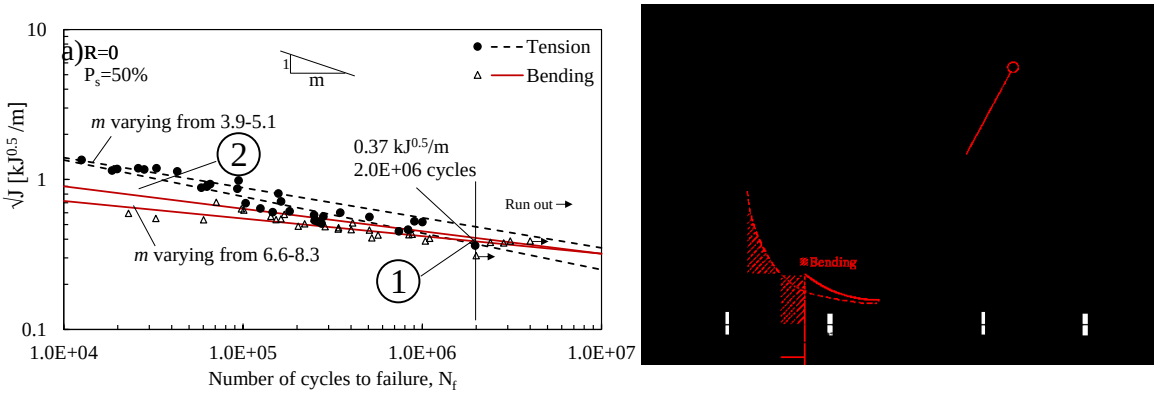

***Figure 1** – a) fatigue resistance curves for laser stake-welded T-joints and b)local stress gradient when loaded in tension and bending*

#93 Probabilistic definition of the apparent fracture toughness of notched elements based on the TCD

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Abstract. Consideration of notched components as cracked ones leads, in general, to over-conservative lifetime predictions. To overcome this situation, different deterministic approaches have been proposed, which, based on the so-called apparent fracture toughness of notched components, enable more realistic failure prediction of notched components to be accomplished. Because such failure models are deterministic, they neglect the data scatter, which is partially related to the notch radius. In this work, a methodology is proposed to derive the apparent fracture toughness (k^N_{mat}) – notch radii (ρ) field in a probabilistic way. This implies, firstly, to convert any apparent fracture toughness into an equivalent value for ρ=0 applying the theory of critical distances (TCD), and secondly, to predict the probability of failure for different notch radii by reducing the results to the same ground conditions and fitting a Weibull cumulative distribution function.

Finally, some examples are presented based on experimental results aiming at illustrating the applicability of the methodology proposed.

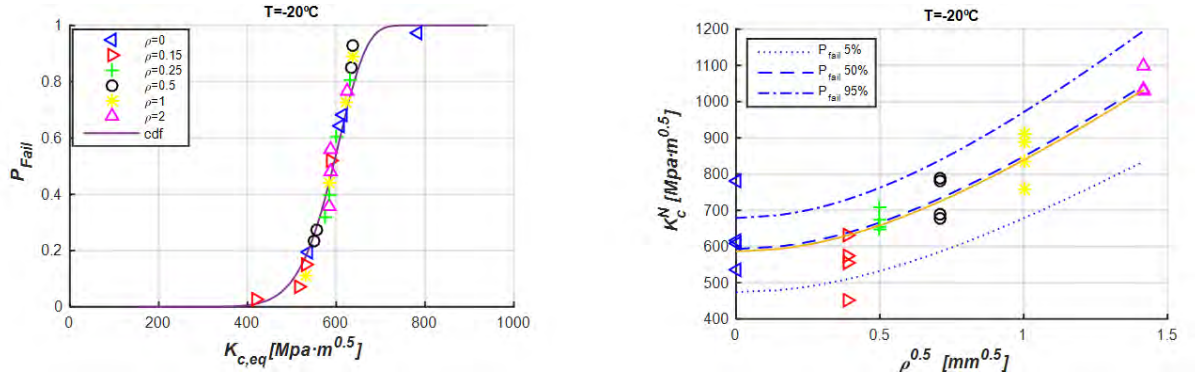

Figure 1 - *Right: Probabilistic apparent fracture toughness prediction for different notches. Left: Weibull cumulative distribution function of failure for the experimental results. (S355J2 Steel)*

#95 Detection of back-surface crack based on temperature gap measurement

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Abstract For large-scale steel structures such as orthotropic steel decks in highway bridges, nondestructive inspection of deteriorations and fatigue damages are indispensable for securing their safety and for estimating their remaining strength. As conventional NDT techniques for steel bridges, visual testing, magnetic particle testing and ultrasonic testing have been commonly employed. However, these techniques are time- and labor- consuming inspections, because special equipment is required for inspection, such as scaffolding or a truck mount aerial work platform. The present authors developed a new thermography NDT technique for crack detection, which is based on temperature gap appeared on the surface of structural members due to thermal insulation effect of the crack. The practicability of the developed technique to through crack was demonstrated by the field experiments for highway steel bridges in service. In this paper, the applicability of the inspection technique based on temperature gap measurement to back-surface crack is investigated by the laboratory testing. A schematic illustration of the experimental setup was shown in Figure 1. In this research, testing was conducted for several specimens with fatigue crack introduced by 4 point bending fatigue test. The specimen material was carbon steel, JIS SS400, and the dimensions of the specimen were 300 mm in length, 60 mm in width and 10 mm in thickness. Temperature gradient of the specimen longitudinal direction was set to 0.04 °C/mm based on the field temperature condition of steel bridge. Result of temperature gap measurement was shown as an example in Figure 2. This figure shows the temperature differential distribution on the reverse side of the crack (crack length =27[mm], crack depth =4.6[mm]). From this figure, it is found that temperature gap clearly appears at the crack of x = 150[mm]. This investigation has revealed that back surface crack can be detected by the proposed technique.

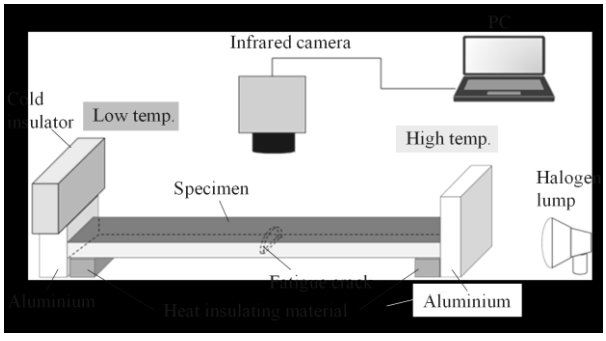

Figure 1 - *experimental setup*

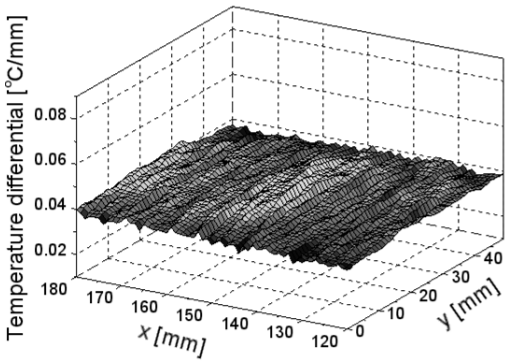

Figure 2 - *temperature differential distribution*

#96 Fatigue damage in spline couplings: numerical simulation and experimental validation

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Abstract One of the most common way to connect two rotating shafts, where high power has to be transmitted is to use spline couplings. These components transmit motion by means of a certain number of engaging teeth, that are subjected to both fatigue and wear caused by variable amplitude loadings and relative sliding.

For as concerns fatigue life, standard design methods consider only a part of the spline teeth to be in contact and this brings to underestimate the components life, so a better understanding about component fatigue behavior may allow to a weight reduction and a consequent increasing of machine efficiency.

On the other hand, wear damage may cause spline coupling run outs; this phenomenon is generally caused by the relative sliding between engaging teeth, due to kinematic conditions (angular misalignment between shafts) or teeth deflection.

In order to obtain the component optimization, both fatigue and wear behaviors have to be taken into account. Standard spline coupling design methods don't properly consider wear damage and they evaluate the fatigue life with strong approximations. For this reason, a better understanding of both fatigue and wear phenomena on spline couplings has to be pursued to develop better design practices.

Aim of this work is to investigate from both numerical and experimental point of view the fatigue damage in spline couplings, focusing on the effect of variable amplitude loadings on the structural integrity of the component.

Specimens consist of steel made spline couplings (42CrMo4) nitrogen-hardened (26 teeth, 1.27mm modulus, 12.5mm teeth width).

Fatigue tests have been performed by means of a special device connected to a standard fatigue machine. In particular, tests have been done by varying the applied torque.

A structural model has also been developed corresponding to the experimental one. Simulations provide both stress field near the tooth root fillet and corresponding sliding distribution. On the basis of the obtained results, fatigue calculations have been done in order to obtain durability data.

Experimental and numerical results have been compared each other and then they have been referred to those obtained with standard design methods, in order to evaluate if and how these classical approaches may over dimension the components.

From the experimental point of view, it is important to highlight that after fatigue tests also wear damage generally appears, due to the relative sliding caused by teeth deflections. This kind of phenomenon is generally completely disregarded in theoretical classical formula, even if it may be a cause of severe damaging conditions.

In any case, all results showed that, concerning the fatigue durability, the actual component life is higher respect to that calculated by standard methods.

Finally, it may be observed that results presented in this work point out that there is a margin to optimize the actual design method in order to obtain lighter and more efficient components.

#97 Fatigue crack evolution following an overload in fatigue cracks subjected to biaxial conditions

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Abstract This work presents a study of the fatigue crack propagation behaviour of structural St-52-3N steel. The study focus on evaluation of overloads effects under biaxial conditions. This is done by measuring the compliance at different stages with respect the overload event. The experimental information was extracted with full-field digital image correlation at few distances behind the crack tip. The experimental data allowed changes in the opening load to be quantified. The experimental procedure previously developed under uniaxial loading conditions was adapted to biaxial conditions (Fig. 1). The changes in the opening load were found to affect the fatigue crack propagation.

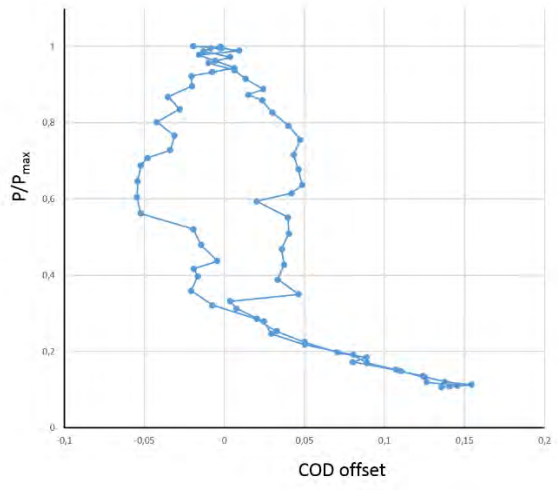

***Figure 1** – Evolution of the load value as a function of the COD offset measured 60µm behind the crack-tip by digital image correlation.*

#98 A non-local damage model for brittle fracture in metallic structures with stress concentrators

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Abstract This work is devoted to the development of the constitutive relations for the description of the defect evolution near the stress concentrators. The original statistical-thermodynamic model of the mesodefect evolution [1] and critical distance theory [2] were applied for this purpose.

In [2] it has been shown that introduction of the length scale parameter is an effective approach to the strength assessment for structures with stress concentrators. However, this parameter is introduced empirically which makes difficult to analyze it connection with structural parameters of the material. Thereby, the aim of this work is to develop constitutive equations which do not require the introduction of the empirical parameters with the dimension of the length.

In this work a model for the description of the collective effects in mesodefect ensembles is proposed. A structural sensitive parameter which has a meaning of an additional strain due to the initiation, growth and coalescence of the mesodefects is introduced as an averaging of the symmetrical tensor characterizing unit defect with the Boltzmann-Gibbs distribution function [1]. Solution to the statistical problem allows us to develop macroscopic phenomenological model describing evolution of the mesodefect ensembles. Constitutive equation for structural parameter was derived under an assumption of the local thermodynamic equallibrium.

The application of the developed approach is illustrated by the numerical simulation of a nonlocal fracture process occurring in a Grade-2 titanium specimen with a stress concentrator under uniaxial tension condition. Introduction of a structural-sensitive parameter allows simulation of the nonlocal character of the fracture near the stress concentrator and propose a physical explanation of the critical distance theory as a length of a dissipative structure growing in blow-up mode kinetics in the defect ensemble.

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#99 Elasto-plastic TCD as a method of failure prediction

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Abstract Development of the method for assessing the strength of engineering structures, considering the effects of the non-locality fracture in the area of stress concentrators, under different loading regime is one of the major scientific interests. Today the method of failure prediction in cases where stress concentrations are present, known as the Theory of Critical Distances (TCD) [1], is one of the most popular methods. The TCD takes a starting point the assumption that that the strength of notched components can be estimated by directly post-processing the entire linear-elastic stress field acting on the material in the vicinity of the stress concentrator. The goal of this work is modification of the classical theory of critical distance for the case of elasto-plastic material behavior for improve the accuracy of estimation of lifetime of notched components. The cylindrical un-notched specimens and samples with stress concentrators of titanium alloy Grade2 were tested under tensile loading with different displacement rate. Mechanical tests were carried out using a 300 kN electromechanical testing machine Shimadzu AG-X Plus and Gopkinson-Kolskiy's split bar. During each test of failure force and time to failure were determined. A finite element software Abaqus© was used to analyse the nonlinear response of the tested Grade2 cylindrical samples containing different stress concentrators. The Simplified Johnson–Cook model was used for plotting the elasto-plastic stress–distance curves, and an elasto-plastic critical distance value was used in order to estimate the strength of the tested samples. The results of elasto-plastic analyses of stress distributions near a wide variety of notches are presented and confirm that failure initiates when applied load provides a existence of area with stress higher ultimate stress of the material and the spatial size of this area is equals half of critical distance. The obtained results showed that the use of the modification of the TCD based on elasto-plastic material behavior gives us estimates falling within an error interval of ±5-10% which means that the elasto-plastic TCD gives more accurate predictions than the linear elastic TCD solution (when using of elastic stress information the error interval is ± 15-20%). In addition, it was shown that the use of an improved description of the stress-strain state at the notch tip eliminates the hypothesis of dependence of the critical distance of the strain rate used in the linear-elastic analysis, and allow us to introduce the critical distances as a material parameter. For the considered titanium alloy Grade 2 the critical distance is equal to 0.46 mm.

Acknowledgements

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#100 The study of the fatigue crack propagation in mixed mode crack growth

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Abstract It is well known that real metals have a complex structure, which is a hierarchy of different scale levels. Under deformation, the structural evolution is observed at all scale levels and leads to irreversible deformation and failure that is accompanied by energy accumulation and dissipation. Investigation of thermodynamics of deformation and failure is a key issue in solid mechanics. The heat generation process depends on both the thermo elastic effect and plastic energy dissipation. The measurement of heat flow near the crack tip allows one to calculate the energy balance under crack propagation and to obtain a new equation for crack propagation. For a long time, infrared thermography is regarded as the most effective method for estimating the power of the heat sources in the process of mechanical testing. The principal solution of the problem of energy dissipation measurement under deformation and failure can be reach by the development of additional system for direct monitor of heat flow. This idea was affectively used for investigation of energy dissipation in hydrodynamics tasks [1]. The previous study of the authors was focused on crack growth problems under an opening or mode I mechanism [2]. However, many service failures occur from growth of cracks subjected to mixed mode loadings. This work aims to study the thermodynamic propertis such as dissipated enrgy during crack propagation in mixed loading mode.

Experimental study of heat flow evolution at the fatigue crack tip was carried out on the plane specimens of stainless steel (AISE 304). The specimens were manufactured from a commercial steel sheet with a thick of 3 mm. The working part of the specimen was 20x80 mm. The process of crack propagation was studied at 20 Hz loading frequency and R=0. The specimens were weakened by double oblique edge crack realise the mixed mode crack growth. For measurening the heat flow was development original system which include infrared camera with a set of algorithms to calculate power of heat source and Peltier-based heat flow sensor.

Several samples were tested. This approach allowed to investigate in detail the processes of the energy dissipation and the geometric features of the deformation plastic zone in the propagation of fatigue cracks in the mixed mode. Analysis of the results allows us to offer the hypothesis of a linear relationship between the rate of fatigue crack propagation and the energy dissipation rate for the study of deformation histories.

This work was supported by the grant of the President of Russian Federation for support of young Russian scientists and leading scientific schools [MK-1236.2017.1] and the Russian Foundation for Basic research [grant number 16-31-00130].

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#101 Impact force reconstruction in composite panels

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Abstract Passive sensing is a branch of structural health monitoring which aims at detecting impacts occurring on aeronautical structures. Impacts are one of the main causes of damage in composite panels (flat, curved or stiffened), limiting the application of these modern components on aircraft. In particular impacts can cause the so called barely visible impact damage (BVID) which, if not detected rapidly, can grow and lead to catastrophic failure (Faggiani, A.; Falzon, B. G., 2010).

The determination of the impact location and the reconstruction of impact force is necessary to evaluate the health of the structure. These data may be measured indirectly from the measurements of responses of sensors located on the system subjected to the impact. The impact force reconstruction is a complex problem, since it is an inverse problem, where the cause is to be inferred from its consequences. Inverse problems are in general ill-posed and ill-conditioned. Therefore, several techniques have been employed in the last four decades and have proven to be effective within certain limitations (Inoue, H.; Harrigan, J. J.; Reid, S. R., 2001). Among these methods, transfer function based methods have been mainly validated for low-energy impact where the linear assumption may be valid. Nonlinearities affect the accuracy in the reconstruction process and thus in the evaluation of damage (Thiene, M.; Ghajari, M.; Galvanetto, U.; Aliabadi, M. H., 2014) and other techniques have been adopted, employing artificial neural networks (ANN) (Ghajari, M.; Sharif-Khodaei, Z.; Aliabadi, M. H.; Apicella, A., 2013) or genetic algorithms (GA) (Yan, G.; Zhou, L., 2009).

In this study, a stiffened panel model developed in CAE/Abaqus is first validated then numerical simulations are used to obtain data for several impacts, characterized by different impact locations and different energy (by changing the impactor mass and/or velocity). Geometrical nonlinearities of the dynamic system are considered in order to represent accurately the mechanics of the composite panel. Then the complex nonlinear behavior will be mathematically modeled through a nonlinear system identification approach, such as ANN, and an intelligent algorithm with global search capabilities, such as GA, will be used in sequence to accurately reconstruct the impact force and, therefore, properly evaluate the health status of the structure.

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#102 Fatigue Behavior Evaluation of Additively and Conventionally Produced Materials by Acoustic Emission Method

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Abstract Additive manufacturing of metals is today one of the most growing fields in materials research. Selective laser melting (SLM) allows to produce metal parts with complicated shapes, but the quality of produced material is relatively low (in compare with conventionally produced materials). The main aims of latest studies is to improve materials properties and reach the same or better quality.

Presented paper shows the comparison of fatigue behavior of SLM and conventional material using copper (Cu7.2Ni1.8Si1Cr) and aluminum (AlCu2Mg1,5Ni and AlSi10Mg) alloys. SLM and standard material samples were subjected to bending fatigue tests which were supplemented by acoustic emission (AE) measurement and fractography analysis. The results from AE measurement allows to analyze fatigue behavior, determine different fatigue stages and compare fatigue behavior of SLM and standard material in more detail.

The results show that the main difference between fatigue behavior of SLM and standard material is not only in total fatigue life (the SLM material has significantly worse fatigue resistance), but mainly in the length of fatigue stages and in mechanism of crack development. As we expected, the fatigue resistance of SLM is strongly affected by amount of production defects.

#103 Evaluation of the fretting wear damage on crowned splined couplings

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Abstract Splined couplings are widely used in many industrial fields and one of the most problematic failure mode of these components is fretting wear. Fretting wear appears because of the relative motions between teeth and it is mainly due to angular misalignments.
The aim of this paper is to set up a procedure in order to identify the entity of the fretting wear damage in crowned splined couplings in real working conditions.
The first Ruiz parameter has been chosen to quantify the wear damage being relatively easy to be obtained from the calculation point of view.
Experimental tests have been performed by means of a dedicated test rig to validate the theoretical results, in terms of iso-Ruiz maps, an example is shown in Figure 1.
The damage entity has also been quantified by measuring the angular rotation before and after each test.
Obtained results confirm that, where the fretting map shows higher values of the Ruiz parameter, the fretting damage becomes more important.

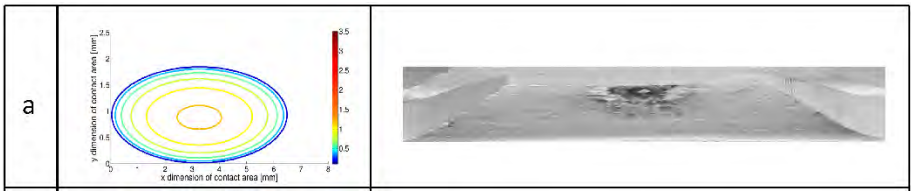

Figure 1 *– Example of worn spline coupling teeth*

#104 Threshold Selection in POT Method for the Extreme Value Extrapolation of Bridge Strain Due to Vehicle Loads

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Abstract Threshold selection is critical for extreme value estimation in the peak-over-threshold method. Overly high threshold results in that little information can be used. And excessively low threshold leads to large bias in parameters estimation of generalized Pareto distribution. In this paper, more than one year's strain data of a long cabled-stayed bridge is used. Four parents are chosen according to the tail distribution of the strain data due to vehicle loads. Lots of samples from these parents distribution are random sampled. By comparing the estimated extreme values at different thresholds and the theoretical values, it is shown that the estimates based on GPD models are larger than the theoretical values in general. Threshold selection should balance the bias and variance. Then an empirical threshold selection method is developed. Finally a real bridge example is chosen to verify this method and satisfied results are obtained.

#105 Mixed mode I/II/III fatigue crack growth in S355 steel

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Abstract The aim of this paper is to describe fatigue crack growth of S355 structural steel for mixed mode (I+II) and (I+III). For the mixed mode (I+II) loading condition performance, the CTS (Compact Tension Shear specimen) were involved. Due to the material limitations, the main dimensions were equal: width W = 42 mm, thickness t = 6.8 mm (f = 10 Hz, R = 0.1). The tests for mixed mode (I+II) were carried out on a MTS 809 servo-hydraulic axial/torsional test machine (Fig. 1a). Unilaterally restrained specimens were subjected to cyclic bending with torsion (mode I+III) with the constant amplitude of moment Ma = 17.19 N·m and stress ratio R = 0. The specimens were cut of the drawn bar, 16 mm in diameter and their dimensions were: length l = 90 mm, w = 10 mm, t = 8 mm. The specimens had an external unilateral notch, 2 mm deep and with the rounding radius ρ = 0.2 mm.
The tests for mixed mode (I+III) were performed on the fatigue test stand MZGS-100 (Fig. 1b) enabling to carry out cyclically variable and static (mean) loading. Crack growth was observed on the lateral specimen surface with the optical method. The test results have been shown as graphs of the crack length "a" versus the number of cycles N and crack growth rate da/dN versus the parameter ΔK. The obtained results have been discussed on the background on the existing fracture mechanics models and crack paths predictions. The fractographic study also supported the obtained experimental data in terms of the identification of the main fatigue crack growth mechanism under mixed mode conditions.

a) b)

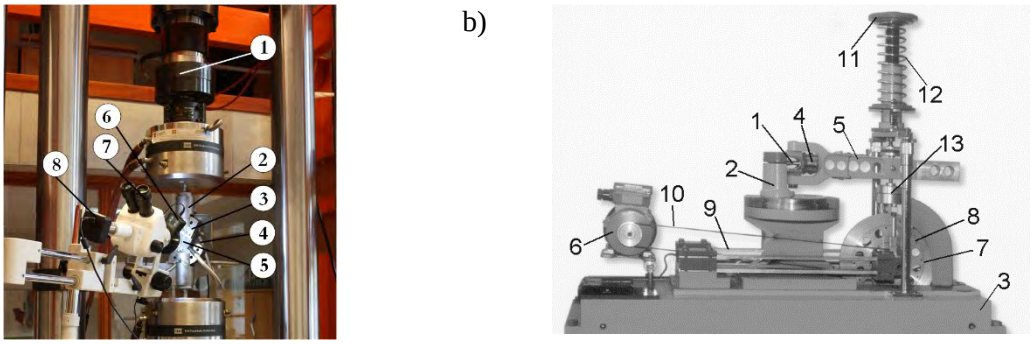

Figure 1 - *Fatigue test stand a) experimental setup; 1 – 50kN MTS load cell, 2 – clevis, 3 – CTS specimen holder, 4 – light source 1, 5 – CTS specimen, 6 – led light source, 7 – eyepieces, 8 – digital CMOS camera integrated with the measurements system operated by the PC and FlexTest console., b) MZGS-100, where: 1 – specimen, 2 – rotational head with a holder, 3 – bed, 4 – holder, 5 – lever (effective length = 0.2 m), 6 - motor, 7 – rotating disk, 8 - unbalanced mass, 9 – flat springs, 10 – driving belt, 11 – spring actuator, 12 – spring, 13 – hydraulic connector.*

#106 Optimal notched specimen parameters for accurate fatigue critical distance determination

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Abstract The Theory of Critical Distances (TCD) is a powerful tool for assessing the strength of any notched component which experiences fatigue loading. The value of the critical distance is therefore a material parameter to be known with accuracy. According to its definition this length has to be calculated by combining the fatigue limit with the Stress Intensity Factor (SIF) threshold range. However, though standardized, the threshold test is challenging from the experimental standpoint. In fact, the critical distance value is usually deduced by considering the fatigue limits of plain specimen and notched specimen, i.e. circumventing the need of a threshold test. In the present paper this latter approach is followed and emphasized since an optimized notched specimen is proposed, for which all the geometry parameters are critically analysed. A round specimen with non-zero-radius V-notch, easy to be machined with a well-controlled radius, has been considered the reference geometry. Initially, the singularity solution of the sharp notch was taken into consideration and the local stress integral, on a length as large as double the critical distance (implementing the line method) was analytically calculated. A series of numerical finite element simulations have been then provided to accurately (errors approx. lower than 1%) simulate the average stress of the actual rounded local geometry. The similitude of the solution was used to scale the analysis, and then the number of free parameters reduced to the dimensionless critical distance and the relative size of the local radius. A correction function was found, which was inverted to recover the integration length and finally the critical distance. This function turned out to be very well approximated as a linear relationship, thus easily reversible. In conclusion, after introducing the relative local radius, and the experimental fatigue notch factor Kf, the critical distance can be found according to the proposed procedure, just implementing a few and easy formulas. Besides this inversion numerical tool, the concept of appropriate dimension sizes is also introduced and deeply discussed in the paper. If the critical distance is very short, such as for high strength metal alloys, the local radius has to be quite small as well, otherwise the stress is averaged in a low gradient region. On the contrary, if the critical distance is large, the local radius is not a problem anymore, but the specimen diameter has to be large too, otherwise the final part of the integration falls, again, in a low gradient stress region. Both these (not desired) conditions lead to a large sensitivity of the experimental errors on the inverse critical distance value. For this reason, the limit dimensions of the specimen are provided to be preliminarily compared on the basis of a tentative critical distance value, which is recommended to be assessed from the material type. A preliminary experimental confirmation result was obtained on a quenched and tempered steel. The critical distance was found by following the proposed procedure, and then successfully compared to the critical distance value derived from the SIF threshold range.

#107 Sensitive detection of Valrubicin - chemotherapeutic drug on plasmonic platforms

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Abstract The development of new plasmonic platforms, equipment for sensitive detection and imaging of fluorescent species located at the platforms will bring new quality to biosensing, molecular diagnostics, and detection of cardiac and cancer markers. The platforms was constructed from silver or gold nanoparticles deposited and arranged on semitransparent silver/gold mirrors. Light-induced localized plasmons in assembles of nanoparticles interact with traveling plasmons in a conductive surface and create extremely strong local electric fields. Fluorescent molecules deposited on the platform surface are exposed to the enhanced local fields and are being excited with higher rate [1].
In this communication we describe the results which allow reliable visualization and detection of medically important molecule like valrubicin deposited on new plasmonic platforms. Spectroscopic characteristics were measured by the setup especially designed and developed in our laboratories.

[1] A. Synak , B. Grobelna, S. Raut, P. Bojarski, I. Gryczynski , J. Karczewski, T. Shtoyko, Optical Materials, 59 (2016) 136-140.

Acknowledgment

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#108 Ultra-Low Cycle Fatigue at Complex Loading Scenarios

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Abstract Structures subjected to earthquakes undergo irregular ground motions. These motions are transferred to the building itself and the frequencies and amplitudes are filtered by the dynamic behavior of the structure. Even in cases of simple static systems these motions can cause complex multiaxial stress states in structural components. As the aim of earthquake resistance design is to reduce the seismic loads by adding or assigning certain regions as dissipative steel elements, large inelastic strains occur on purpose in such parts. These deformations appear in multiple cycles with varying amplitudes.

The phenomenon of degradation caused by inelastic cyclic loading known as ultra-low cycle fatigue (ULCF) seems to depend on the current stress state and is subject of current research. Micromechanical damage models based on the idea of void nucleation, growth and coalescence consider triaxiality time history, Lode's parameter evolution as well as accumulated plastic strains. In addition empirical approaches have been developed within the last 20 years. Typically central notched tensile tests (CNT) are used to adapt to distinctive stress triaxialities (T≈0.4-1.7) and investigate the fatigue behavior. Specimen for pure shear deformations (T=0) are exceptions especially with respect to fatigue. Specific component tests e.g. H-beams welded to head plates or braced frames are also published, but their significance is limited to the individual problem. The validity of the micromechanical damage model needs to be questioned and proved for the whole range of stress states as these are mostly calibrated with the CNT and then extrapolated to lower triaxialities. Furthermore, experiments with monotonic loading at low triaxialities (T≈0-0.2) show big differences compared to the CNT range.

In the event of an earthquake both situations occur - complex multiaxial inelastic deformations meet the stress state and strain history dependent phenomenon of ULCF. To prove the resistance against this failure mode, most design codes help engineers by postulating limiting plastic deformations or a transfer to specific geometric situations and their limitation. These strain limitations are a caution guess rather than based on material scientific facts. Investigations over the whole range of relevant stress states on the influence of the major characteristics of seismic loads are indispensable.

This article describes systematic investigations on ULCF under multiaxial stress states and variable loading sequences. The tests are performed on tubes of medium strength structural steel S355 which are welded on baseplates. The multiaxial stress states are applied by bending respectively twisting the tubes, so that strains up to 30 % per cycle and stress triaxialities between 0 and 0.6 occur. With this specimen and test setup arbitrary stress states in this range could be tested and also defined load sequences along different paths. In total 120 tests have been subjected to constant and variable amplitude loading. Different fracture modes and origins of fracture initiation have been observed. These experiments, their evaluation and documentation are presented within the article.

#109 Preparation and characterization of silver@silica core-shell structure to obtain new plasmonic platforms

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Abstract Metal nanoparticles have several intriguing properties including optical nonlinearity specific heat and magnetism [1,2] which differ from those of their bulk states. Recently, the studies showed that silver nanoparticles introduced into different organic or inorganic fluorophores, would greatly enhances their efficiencies. Fluorophores close to noble metallic nanoparticles show exciting and desired properties like higher brightness and increased photostability [3]. However, fluorescence quenching will occur if fluorescent probes are situated in the vicinity of isolated colloidal metal particles in suspension. Much attention has been paid to control distance between fluorophore and the nanoparticles. Therefore, an active research has been focused on the preparation of new luminescent materials based on silver@silica structures, relies on the investigation of novel strategies to enhance the fluorescence emission intensities of organic or inorganic fluorophores. Specially, silver nanoparticles where chosen as the core of these structures, owing to its LSPRs in the visible region of spectrum and its high conductivity.

In the present work, we obtained new luminescent materials based on core-shell structures. The structures were prepared by the sol-gel method. The mean particle size of silver particles were estimated from UV-Vis absorption spectra and transmission electron microscopy (TEM). Moreover, obtained structures where examined by X-ray diffraction and infrared spectroscopy (IR).

Acknowledgment

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#110 Enhanced fluorescence of NILE RED in TiO_2 and SiO_2 matrices

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Abstract Nile Red - polarity highly sensitive fluorescent molecule is very popular in biosensing due its intensive solvent dependent absorption and fluorescence band shifts .
The platforms bring new quality to biosensing, because fluorescent molecules deposited on the plasmonic platform surface are exposed to the enhanced local electric fields and are excited with higher rate constant. Due to interactions with surface plasmons the brightness of fluorophores is greatly enhanced [1,2]. The aim of the study was to examine the fundamental characteristics of the luminescence of Nile Red in the two matrices based on silicon dioxide and titanium dioxide in the form of thin layers deposited on new plasmonic platforms.

[1] A. Synak, B. Grobelna, S. Raut, P. Bojarski, I. Gryczynski, J. Karczewski, T. Shtoyko, Optical Materials, 59 (2016) 136-140.
[2] I. E. Serdiuk, A. Synak, B. Grobelna, I. Gryczynski, and . Bojarski, J.Phys.Chem.C,121, (2017) 636-648.

Acknowledgment

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#111 Evaluation of rotational deformation in compact specimens for CTOD fracture toughness testing

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Abstract Crack Tip Opening Displacement (CTOD) is an elastic-plastic fracture mechanics parameter, and has been widely used for the fracture toughness evaluation of elastic-plastic materials such as steel. Most of the CTOD fracture toughness standards such as WES1108, BS7448 and ISO 12135 have used the plastic hinge model to calculate the plastic component of CTOD. On the other hand, ASTM E1820 and ISO 15653 Annex-E have adopted another calculation method, the conversion of *J*-integral into CTOD, because of a biased idea that the plastic hinge model is doubtful. These two different CTOD calculations do not always result in an identical CTOD toughness value for a certain loading condition, and one method should be reasonably selected to avoid confusion. The authors previously investigated the rotational deformation of three point bend specimens, and a rotational center was apparently demonstrated in each three point bend specimen. However, it has been unclear whether the plastic hinge model is reliable in other standard fracture toughness specimens such as compact specimens.

In this study, 3-D elastic-plastic finite element analysis was conducted by using the fine mesh crack tip model of a compact specimen. The rotational center was obviously recognized in the ligament of the compact specimen, and the plastic rotational factor, r_p, was reasonably obtained, as compared to reference data.

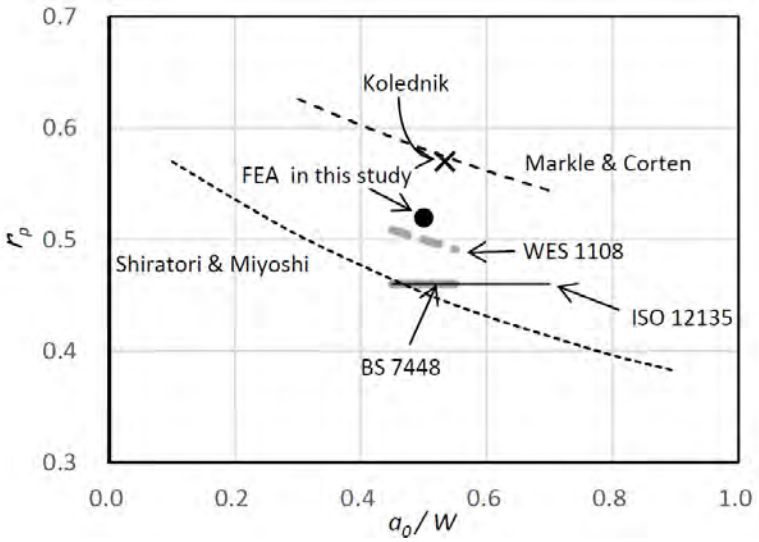

Figure 1 – *Relation between non-dimensional crack length and plastic rotational factor.*

#112 Modelling of mechanical behavior of composite structures using the experimental data from embedded optical fiber strain sensors

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Abstract The problem of analysis and prognosis of mechanical behavior of modern composite materials and structures during their manufacturing and exploitation is urgent, what is confirmed by a large amount of recent dedicated studies. One of the most perspective approaches in structural health monitoring of composite structures during in-service loads relates to creation of the smart-materials and smart-systems based on the sensor elements. The data obtained from such sensors under the structures' operation conditions can be used for monitoring of their mechanical state as well as for improvement of mathematical models of fracture processes prediction.

The aim of this work is to develop combined numerical-experimental technique for assessment of mechanical characteristics and resource of polymeric composite structures. Numerical part of the technique is connected with finite element modelling of mechanical behavior of composite structures under quasi-static loading. Experimental part is based on measurement of internal strains via fiber Bragg gratings (FBG) sensors embedded into composite laminates.

In the proposed scheme, the experimental data is used for validation of numerical modeling results in order to create models capable to reliably predict the mechanical behavior and further failure of composite structures. In some cases, mechanical material constants of composites obtained with the standard tests may not accurately reflect the real processes. Thus, the error of the numerical models may exceed permissible tolerance. For refinement of the model parameters an iterative algorithm is offered that comprise solution of the inverse problems in accordance with the real-time information received from FBG sensors to ensure a match with a given accuracy of numerical and experimental results. This allows to create numerical models of the structures that consider the microstructural parameters of the composite material with better precision.

The proposed scheme of the mechanical constants search is implemented and demonstrated on the test examples. Possibility of refinement of numerical models based on measured by FBG sensors strain data is shown both for quasi-static state of strain and for progressive failure analysis.

#113 Energy description of fatigue crack growth process - theoretical and experimental approach

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Abstract

The aim of the paper is the presentation of the energy methods in description of the fatigue crack growth rate (FCGR) process in structural steel components. In the literature and engineering practice, the ΔK – approach is preferred in construction of the FCGR diagrams. One of the main disadvantages of force approach, is a mean stress effect, reflected in a well-known stress R-ratio effect on FCGR. The second disadvantage seems to be inconsistency in closure estimation with ΔK and description only in the linear-elastic range. In this paper, two energy approaches are presented – ΔH and ΔJ. The kinetic equations based on energy parameters, describe synonymously the kinetics of fatigue crack growth under uniaxial fatigue loading. It has been demonstrated, that the energy description – based on dissipated strain energy density – ΔH is independent from R-ratio. On the other hand, the ΔJ – based on kinetic fatigue fracture diagrams (KFFD) is effective in case of the cyclic mixed mode loading condition. All theoretical and numerical calculations based on ΔJ, ΔH strain energy density parameters were compared with experimental results obtained for different type of alloys.

#114 Shape Memory Alloy Based Dampers for Earthquake Response Mitigation

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Abstract: Passive control techniques have shown to be an effective strategy when aimed at structural preservation for seismic events. These systems are designed to eliminate or at least to reduce structural damage to buildings or infrastructures by limiting the transmitted displacement (Seismic Isolation techniques) or by absorbing the energy of the seismic event (Energy Dissipation techniques). Usage of energy dissipation dampers based on Shape Memory Alloy (SMA) wires is one of these techniques, which is still improving to cope with today's civil engineering needs. Shape memory alloys have many interesting properties that can be utilized in these applications, namely their superelasticity, memory effect and near strain-rate independence.

The aim of this study was to develop a new iteration on this type of devices, along with a fully-fledged methodology to design them for any appropriate application. The underlying concept for this device is the use of a double counteracting system of pre-strained SMA wire sections as the dissipating component. By using pre-strained wires, this design focuses on maximizing energy dissipation, partially relinquishing the re-centering capabilities of the device. The methodology begins by choosing one of several basic layouts of the device, each designed for a specific range of allowed load and displacement. Then the device's capabilities can be fine-tuned by selecting the appropriate wire configuration, i.e., by defining the number of wires per section and their length between fixation points.

In this paper, a downscaled prototype based on this design methodology was tested. The main objective was to validate the basic mechanical concepts. Three different wire configura-tions were used, in order to better characterize the SMA wire behaviour when used in this arrangement and to improve our understanding of their influence on the device's capabilities.

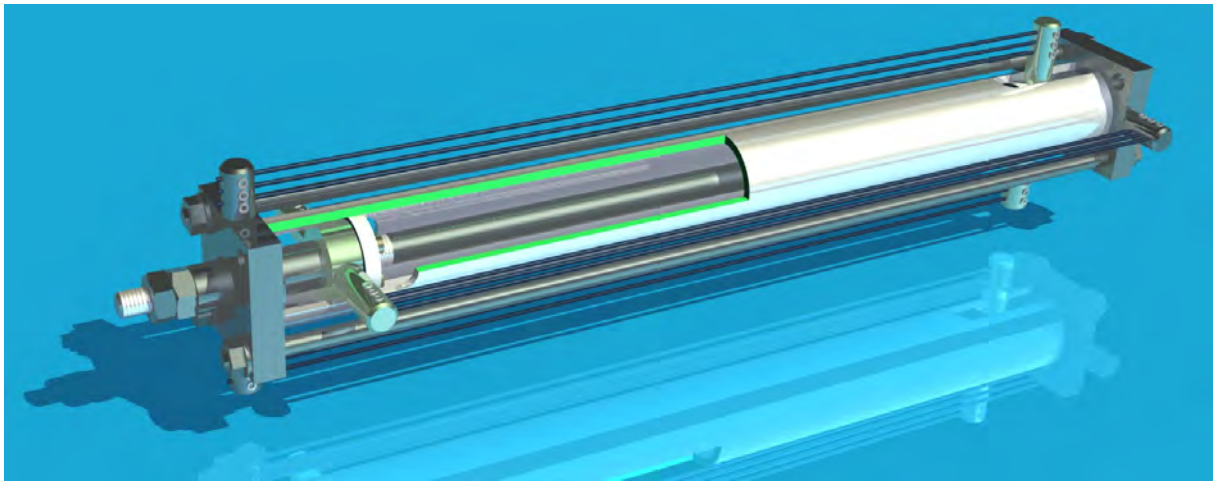

***Figure 1** – Shape Memory Alloy damper virtual prototype*

#116 Random variables in the Offshore Wind Turbine fatigue reliability design with Kriging surfaces

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Abstract: The fatigue design of Offshore Wind Turbines (OWT) is one of the most resource demanding tasks in the OWT design process. Due to its long term cumulative character assessing fatigue damage in the design phase involves a significant amount of computational work that limits the development of a comprehensive probabilistic description. As a consequence, achieving a robust fatigue design of an OWT and increasing the awareness of the designer about the system's behavior is a difficult and demanding task.

For some components of OWTs, fatigue is still a major driver of failure. Developing techniques that reduce the amount of effort needed to accurately analyse fatigue within a probabilistic approach is therefore a topic of major interest.

This is the case of the usage of Kriging surrogate models for probabilistic purposes. These models recently gained interest in the probabilistic analysis of ultimate limit states related with extremes responses. For fatigue limit states their application is relatively less wide. Nevertheless, they show a high potential for improving the probabilistic assessment of the fatigue design.

A methodology for the analysis of OWT towers sustained by Kriging models and extreme values theory with extrapolation techniques is applied. Due to the stress variability and its non-linear character the short-term fatigue damage variability is high and converging the stochastic field approached by the surrogate model in relation to the real observations is challenging. A thorough analysis of the different components that load an OWT and are more critical for the tower component fatigue life is required, and therefore, presented and discussed in the current paper.

A statistical assessment is developed and sets a support analysis for the creation of the Kriging response surfaces for fatigue analysis. NREL's 5MW monopile turbine is used due to its state of the art character. The most critical variables in the Design of Experiments are identified and a sensitivity analysis is conducted to identify which variables are most prominent in the quantification of the short-term damage uncertainty in the tower. The decoupling of the different external contributions for the fatigue life is a major contribution of the work presented. Guidelines are drawn for the creation of surrogate models to analyse fatigue of OWT towers and the most relevant conclusions are presented in an industry oriented outline regarding the most critical stochastic variables that influence OWT fatigue life.

#118 The methodology of transformation of the nominal loading process into a root of notch

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Abstract: When a structural component contains a notch then the failure may start from the notch root due to growing of the crack. To evaluate the fatigue strength and fatigue lifetime of the component is necessary to know stress-strain state in the root of the notch in the form time depending process of the stress or strain. Let us note that direct measuring of stress i.e. strain in the notch is in many cases difficult and sometimes is technically unbuildable. One of the option how to solve this problem is measuring of time-varying nominal stress (strain) and then transforming this value into root of notch. If we want to use such transformation methodology it is necessary to carry out the following tasks

- chose the suitable transformation method for elastic-plastic area of loading
- define stress-strain characteristic which takes into account the loading history of the loading process with stochastic amplitudes
- define the algorithm enabling continual computation of nominal stress transformation into root notch

The proposed methodology is necessary to prove by direct measurements in the notch (which allows that) and also confront with the fatigue lifetime of the component obtained by analytical and experimental examination.

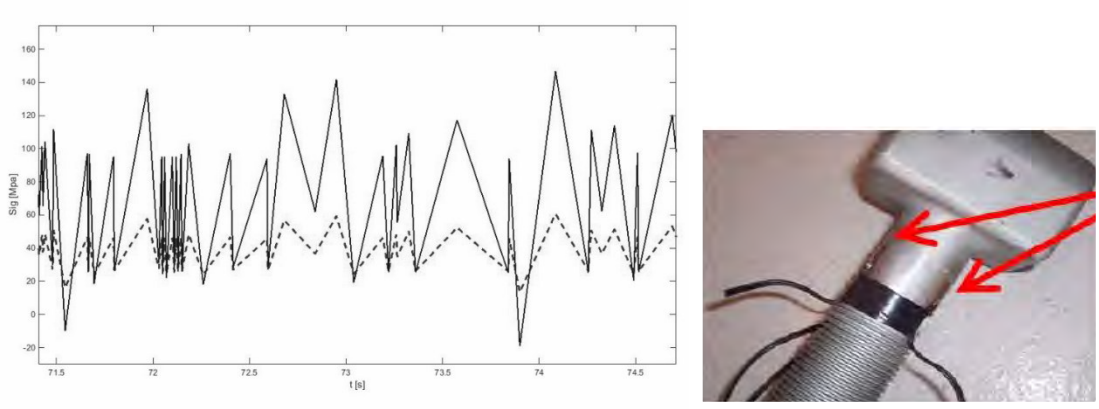

Figure *Nominal stress process (measurement)----- and transformated into a notch ——*

#119 Modification of metallic surfaces by duplex treatments involving severe shot peening, pulsed electron beam and nitriding

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Abstract Long term surface peening, such as the Ultrasonic Shot Peening (USP), was developed to upgrade directly the mechanical properties of the materials as well as a surface activator prior to chemical treatments such as Plasma Nitriding [1]. The High Current Pulsed Electron Beam (HCPEB) technique is also a recent technique that has been proved to increase surface hardness as well as improve wear and corrosion properties [2]. These techniques create a deformed graded surface for which the grain size reduction, the increased grain boundary density and the introduction of structural defects (twins, dislocations, vacancies …) improve directly the properties.

In the present work, stainless steels (316L and 304L) were treated by USP at room as well as by HCPEB under different processing conditions. The evolutions of the structure in the nanocrystalline surfaces and sub-surfaces were analyzed at the light of a quantitative analysis of the deformed state using a recently developed procedure based on the analysis of Geometrically Necessary Dislocations (GNDs) obtained from the analysis of electron backscattered diffraction (EBSD) orientation maps [3].

Duplex surface treatment were carried out by giving the USP or HCPEB plastic deformation surface treatments a subsequent Plasma Nitriding. The goals of these duplex treatments is to increase further the surface and sub-surface hardness while bringing strong compressive residual stresses at the surface to improve fatigue properties. The characterization procedure, which was initially developed to study quantitatively the surface and sub-surface microstructural changes issued from USP, has been extended to the analysis of these duplex treatments. The presentation will detail the structure and property modifications associated with the various USP + nitriding and HCPEB + nitriding duplex treatments.

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#120 The conditions for long-term monitoring of the pipelines safety in operation

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Abstract The safety of the high-pressure pipeline systems can negatively affect occurrence of non-standard operational states. This can primarily occur in operation of turbo-compressors at the compressor stations where we can expect an unwanted vibrating due to existence of the dynamic loading. Let us have another case, the line parts of such pipelines where the walls could sometimes be weakened by the unwanted corrosion defects. In both cases the safety of operation can be exposed by additional bending loading of the pipeline e.g. due to decreasing of sub-soil. In this contribution, there will be introduced monitoring systems which can monitor such negative events in a real time. More closely will be explained selection of suitable sensors and their deployment along critical place, evaluation of measured data and conditions of valuation the operational safety. Furthermore, there will be presented results obtained from measurements of existing real monitoring systems of safety for given pipeline systems.

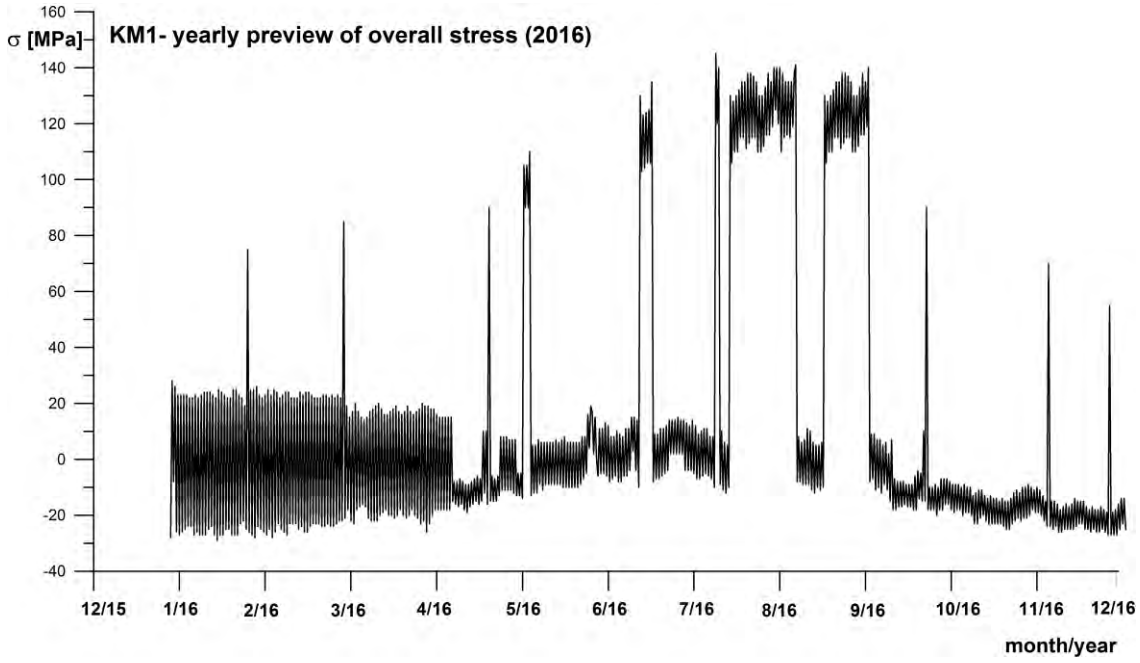

Figure 1 *– Long-term loading process of pipeline at the compressor*

#121 Structural integrity and life assessment of a wind loaded cylindrical steel shell structure

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Abstract The structural integrity and life assessment can be considered as a mandatory request in the civil engineering designing and manufacturing process.

The paper is presenting the procedure for determination of crack acceptability based on fracture toughness with failure assessment methods (FAD-1 and FAD-2) which is applied to a cylindrical steel shell structure with welded joints which is having the wind as a main load.

The assessment is using BS7910/2013. Thus were assessed common types of flaws met at steel shell cylindrical structure elements using failure assessment diagrams – level 1 – FAD-1. The results are presented the acceptability level for each type of flaw with comparative graphs, determining also the critical dimension of the flaw.

For each flaw was calculated the failure assessment diagram (FAD-2). Different comparisons between group of flaws were done, revealing the critical crack like flaw. Also the critical value of flaw dimensions were calculated for each flaw type.

A major contribution in the paper is presenting the procedure for determining the safety in service of the shell steel structures using engineering critical assessment approach.

The methodology establishes clear rules for assessment of structural elements with cracks, determining the initial flaws, assessed flaws and critical values of the cracks. A detailed fatigue design and assessment procedures are presented.

Using CrackWise software, was applied fatigue based engineering critical assessment on a real case – the billboard tower like steel shell cylindrical structure. For the fatigue evaluation, a detailed wind load calculation was done taken into account the cycles given for a wind recording (data supplied by the Romanian INMH institute). Following the structural analysis of the five load cases, was assessed the stress in the structure segment joint. Using Rainflow algorithm, the results were processed and was determined the block of stresses with stress ranges and the appearance frequency of them.

For each type of flaw the ECA was applied and resulted a plotted graph indicating the number of years until failure and the critical flaw dimension. The results were compared and were revealed the most critical flaws – with the lower number of years until failure.

Based on the detailed procedures described in the paper, on conclusions to the assessment done on each type of flaw, the assessment methods can be applied very easy in current design practice with different material characteristics.

#122 A numerical analysis of the plastic wake influence on plasticity induced crack closure

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Abstract Fatigue crack closure has been studied by means of finite element method since long time ago. Most work has been performed considering bi-dimensional models. Lately, the use of three-dimensional models has been extended. Nevertheless, the methodology employed has been taken from that developed for bi-dimensional cases.

There are a great number of previous bi-dimensional studies which analyse different numerical parameters and optimise them. The current computational capabilities allow a comprehensive study of the influence of the different modelling parameters in a similar way to those studies carried out with bi-dimensional models, with the advantage, that the evolution along the thickness of the analysed parameters can be taken into consideration.

In particular, one of the key issues is related to the plastic wake length which is developed during the previous loading cycles. This residual stresses have a great influence on the crack opening and closure values. As the numerical analysis are complex and computationally expensive, the length of the simulated wake is a critical parameter.

In this work, a comprehensive study of the effect of the plastic wake in fatigue crack closure is made. On this purpose, a CT aluminium specimen has been modelled three-dimensionally and several calculations have been made in order to evaluate the influence of the simulated plastic wake length. The numerical analysis is made in terms of crack closure and opening values as in terms of the stress and strain fields near the crack front.

#125 Mitigation of Weld Residual Deformations by Weld Sequence Optimization: Limitations and Enhancements of Surrogate Models

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Abstract Among all possible joining methods, fusion welding is still by far the most widely used. During the process, solidification and cooling of the filler material cause local shrinkage which in turn generates unwanted residual stresses and residual deformations. A variety of techniques have been developed over the years to minimize stresses and deformations but for welds consisting of several passes, bead sequence is still the most important parameter as it strongly affects the final stress and deformations states.

In order to avoid costly and time consuming trial and error welding experiments, numerical simulations based on the Finite Element Method are extensively used to predict residual stresses and deformations. Usually a thermal analysis is first carried out to capture the time dependent temperature distribution in the welded structure and these results subsequently serves as an input for a mechanical analysis. Depending of the size of the model and the number of beads, the total simulation time can vary from one to several hours for a two dimensional analysis and from one to several days for a three dimensional analysis.

To be reliable, optimization techniques must cover the full range of possible combinations. Unfortunately the number of combinations grows very fast with the number of alternatives. A simple symmetrical eight beads X-weld connecting two pipes together can for example be welded in 560 different ways (symmetry having been taken into account). Simulation of the whole set of combinations it therefore unfeasible and use of surrogate algorithm is mandatory.

Surrogate models make use of a very limited but carefully chosen set of combinations to approximate the behaviour of the complete set. Only a few simulations need to be run and use of intermediate and final results in an optimization algorithm allows to minimize the value of a specific outcome: maximum residual stress or deformation for example. In several applications where events do not strongly depend on each other and are of the same order of magnitude, results are remarkably good.

Unfortunately in cases where some events dominate and drastically modify the influence of other events, surrogate models tend to behave poorly. A typical example of such an event is a
sudden stiffening of the structure caused by the addition of one particular bead. In such cases, the straight forward standard procedure fails and improvements are necessary.

The goal of this study is to mitigate welding deformations in two simple but fundamental geometries, namely plates and pipes, respectively connected by a symmetrical 8 beads X-weld. When joining the two plates together, one was constrained at the end while the other was left free and as a result of adding beads, the free plate moved upwards and downwards. When joining the two pipes together, no particular constraints were applied and a result of adding beads, the whole weld region moved inwards and outwards.

Reasons why the surrogate algorithm cannot give reliable results in these two cases are precisely pointed out and modifications are introduced to correct the problem. The enhanced algorithm is then shown to be able to accurately predict displacements and to find the bead sequence giving the smallest possible displacement.

#127 Evaluation of slip line theory assumptions for integrity of defected welds loaded in tension

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Abstract In order to assess the safety and reliability of a structure under working conditions, periodical integrity assessment is a major requirement. In case of welded structures, the presence of defects is an impediment for the fitness-for-service study. The existence of local strength variations in the weld region and the softening or hardening of Heat Affected Zones (HAZ) gives rise to complexities for the assessment of weld defects, which are not yet fully understood. Whereas fracture mechanics and plasticity theories have been used to analyze the elastic-plastic structural response of defects, many theoretical concepts are built on the assumption of material homogeneity.

This paper is concerned with the plasticity analysis of defect response in welded connections loaded under uniaxial tension, using the concept of slip line field theory. Taken as a research subject is the single edge notched tension (SE(T)) test specimen. Slip line analysis assumes (among other conditions) rigid plasticity of a homogeneous body, which yields infinitely thin lines of plastic shear. Knowledge of slip lines allows to evaluate limit load, which can be used to estimate crack driving force.

An analytical solution of the SE(T) configuration predicts straight slip lines, oriented 45° with respect to the loading direction. In case of weld notches, this prediction becomes invalid as welded connections are heterogeneous and show strain hardening. This yields deformation bands rather than lines, which are no longer straight. In a joint research project between Ghent University and University of Maribor, it is attempted to understand the development and trajectory of these bands, and their link with crack driving force. This paper reports on the results of an experimental program, supported by finite element analysis.

Single Edge notched Tension (SE(T)) specimens were extracted from butt-welded steel (S690) plates. Welds were designed to have an overmatching region and an undermatching region, thus producing a strong strength gradient at the interface in between. Notches located in both regions were studied separately. Deformation bands were derived using Digital Image Correlation (DIC) and characterized by devoted post-processing. To assess the relation between maximum shear stress (Tresca) on which the slip line theory is based on and equivalent plastic strain (PEEQ) obtained from experiments, finite element simulations were performed.

The attained results are a basis for the development of an analytical crack driving force estimation scheme that takes into account weld heterogeneity. Such scheme is expected to assist in the improvement of existing (standardized) defect assessment procedures.

#128 Analysis of the environmental degradation effects on the cables of "La Arena" bridge (Spain)

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Abstract After nearly 25 years of service, some of the wires of the cables of "La Arena" bridge started to exhibit the effects of environmental degradation processes. "La Arena" is cable-stayed bridge with 6 towers and a reference span between towers of about 100 meters. The bridge is less than 1 km far from the Atlantic Ocean, located in the highway between Santander and Bilbao (Spain).

After a maintenance inspection of the bridge, evidences of corrosion were detected in some of the galvanized wires of the cables. A more in-deep analysis of these wires revealed that many of these wires exhibited loss of section due to the corrosion process. In order to clarify the causes of this degradation event and to suggest some remedial actions, an experimental program was designed. This program consisted of tensile and fatigue tests on some cable samples of the bridge together with a fractographic analysis of the fracture surfaces of the wires of these cables (Figure 1) and some hydrogen measurements on the wires (hydrogen embrittlement could be another effect of the environmental degradation process).

Once the type and extension of the flaws in the wires was characterized, a structural integrity assessment of the cables was performed with the aim of quantifying the margins until failure and establishing some maintenance recommendations.

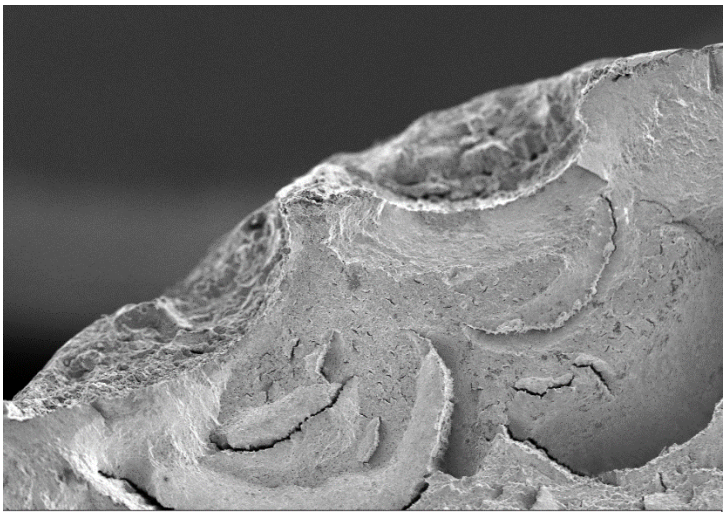

Figure 1 – *Corrosion type defect in the wires of the cables*

#129 Anisotropy and size effect in tensile mechanical properties of Al-Cu-Li 2198 alloy

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Abstract Aluminum copper (Al-Cu) 2024 alloy has been widely used in various aircraft sections due to its high damage tolerance capabilities for many decades. Innovative aluminum-copper-lithium (Al-Cu-Li) alloys such as AA2198, have been recently developed and are supposed to replace AA2024 in aerospace industry applications. Third generation Al-Cu-Li alloys provide improved mechanical properties and damage tolerance that are quite often associated with the Li concentration that enables the formation of additional strengthening precipitates besides the *S* type particles, e.g. *δ*' (Al_3Li), T_1 (Al_2CuLi) particles. One major disadvantage in Li added aluminum alloys is the anisotropic tensile mechanical properties, often associated with the grain size difference for the case of second generation Al-Cu-Li alloys of the previous decade. Anisotropy effect is more evident in thicker products than sheets (e.g. plates) that show short transverse ductility. So far, literature review on the anisotropy effect for third generation Al-Cu-Li alloys still remains rather limited.

In the present work, the anisotropy effect on tensile mechanical properties on an Al-Cu-Li alloy w.r.t the thickness of the specimens (sheet vs plate) will be investigated. Additionally, occurring size effects between macro (300 mm total length) and micro (0.4 mm thickness and 50 mm total length) tensile specimens will be discussed. The mechanical behavior of AA2198 will be examined by taking into account experimental results from micro-flat and standard tensile specimens. Additionally, the results will be discussed by taking into account the thickness variance (sheet of 3.2 mm and plate of 5.0 mm thickness) along with hardness measurements and quantitative metallographic analysis. Preliminary results showed that the micro-flat specimens exhibited decreased tensile ductility that was attributed to the low available grain structure for deformation. Sheet and plate specimens exhibited approximately the same quasi-static mechanical properties in all rolling directions.

#130 Influence of material non-linearity on load carrying mechanism and strain path in stiffened panel

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Abstract This paper investigates the influence of material non-linearity on load carrying mechanism and strain path in stiffened panel. First, clamped stiffened panel with dimensions of 0.96 m x 0.96 m were penetrated with rigid indenter until fracture took place. Panel material was characterized with standard tensile tests using flat test coupons extracted from the face sheet of the panel. Failure strain for different element lengths was calibrated using iterative state-of-the-art procedure. Numerical finite element simulations were performed using failure strain calibrated with tensile tests. Comparison of numerical and experimental force-displacement curves clearly shows that the approach is not sufficient for reliable element size independent numerical simulations.

Keywords: ship collision, finite element simulations, fracture prediction, tensile tests, large-scale experiments

#131 Experimental study of criteria of the beginning of the postcritical deformation stage of structural steels at various types of stress-strain states

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Abstract. This work is devoted to theoretical and experimental study of material behavior on the postcritical deformation stage and developing of scientific foundations of the prediction of failure processes, risk assessment and accident prevention by taking into account the postcritical deformation stage of materials. Postcritical deformation stage connected to the accumulation of damages, structural failure and fracturing processes and reflected on the strain curve as a descending section. Each point on this stage of deformation can correspond to the moment of the loss of load-carrying ability because of transition from stable to non-equilibrium process of damages accumulation.

When the postcritical deformation stage is taken into account, it reveals reserve of the load-carrying capacity of structures. With the aim of creating and developing of mechanical models of softening media, the necessary data about the moment of transition of deformation process from elastoplastic to postcritical deformation stage. For stydying of elastoplastic and postcritical behaviour of steels under various types of the stress-strain states, the uniaxial tension, proportional and non-proportional tension-torsion tests at room and high temperatures were carried out. The biaxial servohydraulic test system Instron 8850 (100 kN/1000 Nm, 30 Hz) were used in tests. For realization of the plane stress state conditions in tension-torsion tests were used thin-walled tubular specimens of different structural steels (20, 40Cr, 20Cr13). It confirms the possibility of realization of the postcritical behaviour at various types of stress-strain states. For cases of plane stress states were realized not simultaneously beginning of decreasing of normal and shear stresses. Different critaria of transition to postcritical deformation stage were analyzed. It was found that maximum value of stress intensity correlated with the start of postcritical deformation for different structural steels and parameters of plane stress-strain states (various ratios of axial and shear strain rates).

The work was carried out in the Perm National Research Polytechnic University with financial support of the grant of the President of Russian Federation for government support of young russian scientists (grant № МК-3293.2017.1).

#132 Hygrothermomechanical behavior of thick composite plates using high order theory

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Abstract

The structures made of materials composite occupies a very great part of research in aeronautical and aerospace engineering considering their specific characteristics in term of lightness and rigidity, during the service these structures are subjected to variable environmental conditions and sometimes extreme in term of temperature and moisture and that causes residual stress, the determination of this stress is highly significant for the reliability of the stages of design and dimensioning.

This study investigates the behavior of thick composite laminates using the high order method through stress calculation, the laminate is subjected to mechanical solicitation and working in a hygrothermal environment, temperature and humidity are taken into account in the calculation of stress,different Simulations are carried out for different types of temperature and concentration (linear, constant, parabolic, etc.) through the thickness of the plate to see the influence on the behavior, the plate size is also taken into account in the simulations (a/b: ratio of length to width, a/h: ratio length to thickness).

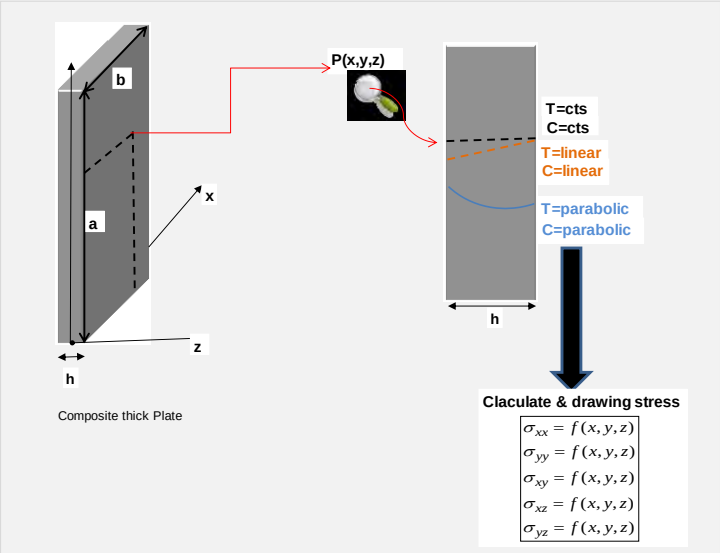

***Figure 1** – Problem Definition*

#133 Study of the Effects of Different Load Tension Levels on Guided Waves Testing applied to Power Line Cables

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Abstract Multi-wire cables are employed in a wide range of applications, among these, power line cables is one of the most extended. Thousands of kilometers of cables are installed in many different locations, including adverse environments such as polluted and salty atmospheres. These factors, together with the age of some of the installations, could lead to the failure of the structure. Among the different structural health monitoring solutions, Ultrasonic guided wave technique has been studied as a potential solution for testing these structures. This research focuses on the study of how the different load tension levels affect the propagation of the guided waves, as well as the capabilities of the technique for the detection of cross-section area distortions. In order to evaluate the applicability of the technique, a scenario close to a real installation setup was developed with lengthy cables. The tests were done at a wide range of frequencies including very low frequencies not normally employed for UGW testing. The results indicate the high influence of the load tension level in the propagation of the guided waves at different frequencies, showing great potential regarding low attenuation behavior at very low frequencies. These results also showed the capabilities of the technique to detect cross-section area distortions located from a long range.

#134 A Comparative Study between Conventional and Elevated Temperature Creep Autofrettage

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Application of the autofrettage processes has become a useful tool of increasing the fatigue resistance for many high pressure components working in dynamic conditions. There are numerous studies related to conventional autofrettage methods such as hydraulic and swage autofrettage whose effectiveness and applicability have been thoroughly investigated theoretically and experimentally over the last decades. However, there are some unusual methods such as elevated temperature creep autofrettage which may be more beneficial compared to the conventional methods in some cases. The idea of the creep autofrettage method is similar to conventional hydraulic autofrettage except for a high temperature which is applied in combination with overload pressure. Overload pressure in the case of creep autofrettage is significantly lower than that pressure for conventional autofrettage as inelastic strains are induced at a smaller level of stresses. This may be more favorable for the cases where the application of very high pressure in autofrettage assemblies may cause structural damage. One of the objectives of this study is to investigate numerically the creep autofrettage compressive residual stress field and its influence on the fatigue life time.

Despite the fact that compressive residual stresses can significantly improve the fatigue lifetime of high pressure parts, the mechanism of fatigue failure under the influence of compressive residual stresses is not always clear. The dominant part of the fatigue lifetime in components without compressive residual stresses is the crack initiation stage, and once a crack is initiated at the surface it immediately propagates inside a component causing fatigue failure. Time for the crack propagation in this case varies from tens to hundreds of cycles, which is significantly less than crack initiation time. However, this may not be the case of components with high compressive residual stresses, where an initiated crack can be arrested at some point of the propagation. That means there may be an underestimation of the fatigue lifetime if it is calculated only for the crack initiation stage as an additional load can be applied to a component if an initiated crack is arrested at some point. The crack arrest phenomenon is also more likely to happen in the case of high pressure components working in aggressive corrosion environments, where cracks are initiated at significantly lower levels of stress compared to non-corrosive environments.

Prediction of the crack arrest in autofrettaged pressure parts is a complex problem as it requires the knowledge not only of fracture material parameters and crack propagation laws but an actual inelastic behavior of a material which is necessary for an accurate prediction of compressive residual stresses after autofrettage as well. In this work a new concept of modelling nonlinear material behavior under cyclic loading is combined with the crack propagation simulation techniques in order to predict the crack arrest phenomena in autofrettaged components.

#135 Selective laser melting combined to plasma assisted nitriding for stainless steel patterning

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Abstract Selective Laser Melting (SLM) can be used for surface patterning by addition of material. It consists in depositing a metallic powder over the entire surface of the sample and then exposing it to laser pulses in such a way that it melts locally. After solidification, a discontinuous mask is formed at the surface of the sample in the form of hemispherical islands. The unfused powder is then blown up with compressed air. The mask thus obtained is adhering to the surface. In this communication, AISI 316L austenitic stainless steel is used as a substrate material whereas bronze and nickel base alloys were used for SLM. Plasma-assisted nitriding treatments on austenitic stainless steel at low temperature (< 420°C) produces the so-called "expanded austenite". Nitrided layers which contain expanded austenite are highly enriched in nitrogen (from 10 to 35 at %) and submitted to high compressive residual stresses. From mechanical considerations, the only possible deformation occurs in the direction perpendicular to the surface. We use such a perpendicular expansion of the layer from the initial surface of the substrate for surface patterning of stainless steel using non-adherent masks [1]. When adherent masks are used in this process, strong distortions of the masks can be observed. Such distortions also include severe plastic deformation of the mask. The role of elastic strain, due to the expanded austenite phase formed by nitrogen diffusion under the mask, is of primary importance to understand such phenomena. Some wetting properties of SLM layers will be also presented in this communication.

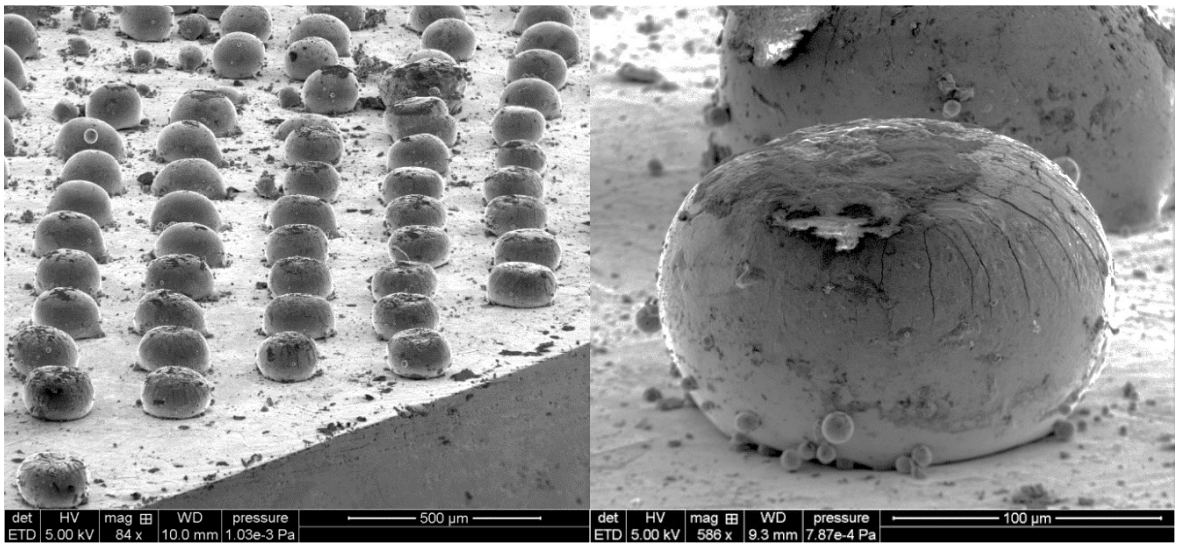

***Figure 1** – SEM images of stainless steel surfaces covered by a discontinuous mask formed by Astalloy spheres obtained by SLM*

[1] G. Marcos, S. Guilet, F. Cleymand, T. Thiriet, T. Czerwiec, Surface & Coating Technology 205, 2011

#136 Evaporation of sessile water droplets and projected water droplets on plasma treated austenitic stainless steel surfaces

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Abstract Heat production accounts for about 70% of the world's primary energy consumption. Better thermal management in industrial processes would be an advance in the energy transition process. In this context, the development of efficient extractors, recuperators, heat exchangers, condensers, sufficiently compact and affordable is an important industrial challenge. Surface patterning (surface texturation, surface structuration) allows the production of a "patterned" surface with some regular array of surface height features on the size scale of several micrometres to some nanometres. Robust and efficient surface patterning manufacturing methods are existing but alternative cheap and flexible technologies are required, especially for metallic surfaces such as stainless steel. Plasma technologies such as nitriding, carburizing and etching by ion bombardment are well adapted technologies for that purpose.

This communication will focus on the evaporation of sessile water droplets on different states of austenitic stainless steel surfaces modified by plasma treatments. We will present the time evolution of the contact angle and of the droplet diameter as a function of time for different temperatures ranging from ambient to 100 °C. We investigate different surface states of austenitic stainless steel AISI 316 L: mirror polished, nitrided with a resulting honeycomb-like structure and patterned by ion sputtering using masks. Two different regimes for the evaporation exist at low temperature: a constant diameter regime and a nearly constant contact angle regime. Our experimental data are analysed through theoretical models for the natural evaporation of a drop, assuming a process controlled by vapour diffusion in the gas phase. Such a classical description applies for polished 316L surfaces. However, we measured an important aging effect on the contact angle due to atmospheric contamination. Such an aging effect is not observed for plasma treated surfaces. However, the classical description for evaporation is more difficult to apply. For patterned surfaces, many small transition regimes, corresponding to local jump of the triple line, were observed.

Finally, the results of projected water droplets, observed by fast camera, on modified austenitic stainless steel surfaces will be presented. The use of projected drops makes it possible to reach temperatures higher than that possible with the sessile losses. With projected drops, it is possible to visualize the Leidenfrost effect by means of a transition temperature (Leidenfrost temperature). The Leidenfrost temperature is greatly increased using plasma assisted surface treatments.

#137 Compatibility of S-N and crack growth curves in fatigue reliability assessment of a welded steel joint

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Abstract Reliability analysis is a crucial phase in securing and assessing the safety status of new and existing structures. One of its main applications is to predict the remaining fatigue life of the fatigue prone infrastructures. Two approaches are used to formulate the fatigue limit state: the S-N curves in combination with Palmgren-Miner damage accumulation rule and the Linear Elastic Fracture Mechanics (LEFM) based fatigue prediction. In both approaches, the safety examination in terms of failure probability and its corresponding reliability index is possible by different reliability analysis methods namely, the Crude Monte Carlo Simulation (CMCS). Since, the fatigue life of the welded joints can be predicted by both LEFM based crack growth and S-N approach, available in the standards such as BS7608, BS7901 and EN1993-1-9, they should be compatible at the failure point. Therefore, the outcomes of the reliability analyses following any one of those approaches are expected be consistent as well. This compatibility is studied for a transverse-weld butt joint under Constant and Variable Amplitude (CA and VA) Loading, by comparing the trend of the Probability of Failure over the number of applied cycles. The influence of the uncertainty related to each involved parameter on the final results is evaluated by performing a sensitivity analysis. For CA loading, the compatibility is found to be less by considering lower stress ranges. This can be related to the different locations of constant amplitude fatigue limit (CAFL), in S-N curves following different standards and threshold stress range, predicted by LEFM. The same conclusion can be reached for VA loading. In that case, the reason is due to the fact that the stress ranges lower than the CAFL or the threshold stress are not considered damaging in the same manner by different approaches.

Keywords: Fatigue; Reliability; Probabilistic method; S-N curve; Linear Elastic Fracture Mechanics

#138 Creep characterization of service-exposed Grade 91 steel in USC Plant

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Abstract Grade 91 steel (Gr. 91) is one of structural components for the Gen-IV reactor systems such as a very high temperature reactor (VHTR) and sodium-cooled fast reactor (SFR). Since the components are designed for up to 60 years at a high service temperature, they are exposed for long-term duration in service. After shutdown and restarting processes in plant operation, an exposed material may generate significant degradation in mechanical strengths compared with unexposed (virgin) material. Thus, it is necessary to investigate the degradation of creep strength (or life) for service-exposed Gr. 91 steel for estimating allowable stress. In this study, creep properties for service-exposed Gr.91 steel sampled from a piping system of an ultra-supercritical (USC) plant in Korea with accumulated operation time of 73,716 hours were investigated. To do so, a series of creep tests for the unexposed and exposed materials was conducted from different applied load levels at the identical temperature of 600°C. The creep properties of the exposed material were compared with those of the virgin one. In addition, the creep life of the exposed material was compared with the creep life data given in RCC-MRx code. The creep strength of exposed material showed a significant reduction compared with that of virgin one. The creep strain rate of the exposed material was much faster than that of the virgin one, and its creep rupture ductility was higher than the virgin one. The grain boundary carbides coarsened in the exposed samples, and the lath width increased compared with the virgin material. The precipitates size increased for the exposed samples.

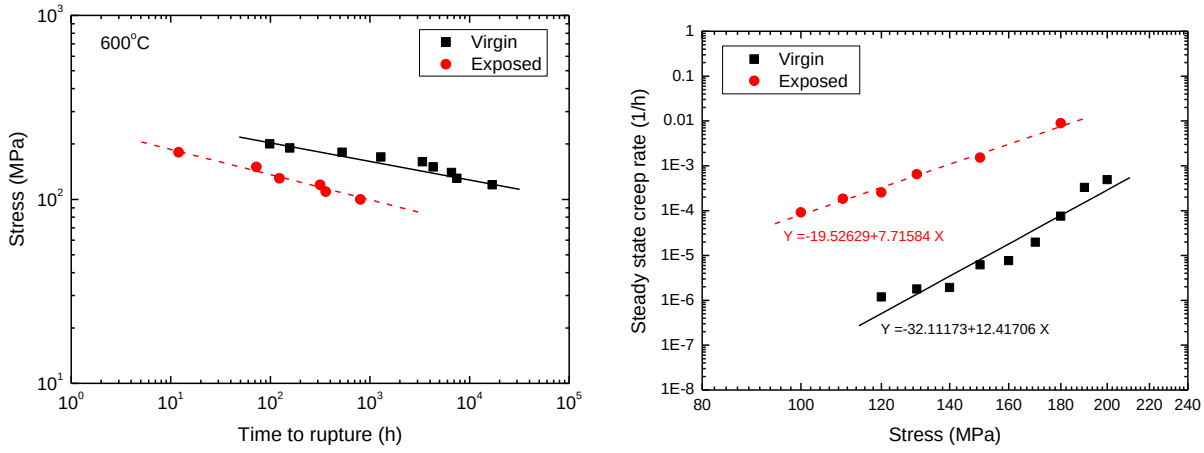

***Figure 1** – Comparison of the creep strength and creep strain rate obtained for virgin and exposed specimens of Gr. 91 steel*

#139 Study of the spatial-time inhomogeneity of inelastic deformation and failure in bodies with concentrators by using the digital image correlation and infrared analysis

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Abstract. The present paper deals with the experimental investigation of the deformation and failure patterns in solids with concentrators of different geometry and estimation of the zone of postcritical deformation of materials. The influence of the loading system stiffness on the behavior patterns of the materials at the elastoplastic and postcritical deformation stages by using the original specimens with complicated geometry was estimated. The work contains the experimental procedure of combined use of the computer vision technique and thermographical analysis in study of the mechanical behavior of carbon steel and Al-Mg alloy, the spatial-time inhomogeneity due to the Lüder's behavior, the Portevin-Le Chatelier effect, the processes of damage accumulation and failure.

Complex experimental investigations of the temporal instabilities and the spatial localization due to the Lüders behaviour, the PLC effect of structural alloys were carried out on the base of combined use of the 3D digital image correlation (DIC) measurement system Vic-3D and the infrared camera FLIR SC7700M. The mechanical tests were provided on the Instron 8850 servo-hydraulic biaxial testing system and the Instron 5989 electromechanical testing system. The assessment of the influence of the loading conditions, the additional cyclic impact and the stress concentrators on the spatial-time inhomogeneity of the plastic flow was performed. Based on the estimation of the strain fields, the evolution of the zones of the postcritical deformation was revealed in specimens with concentrators during uniaxial tension (Fig. 1). The work was carried out in the PNRPU in the Center of Experimental Mechanics with support of the Russian Science Foundation (Project 16-19-00069).

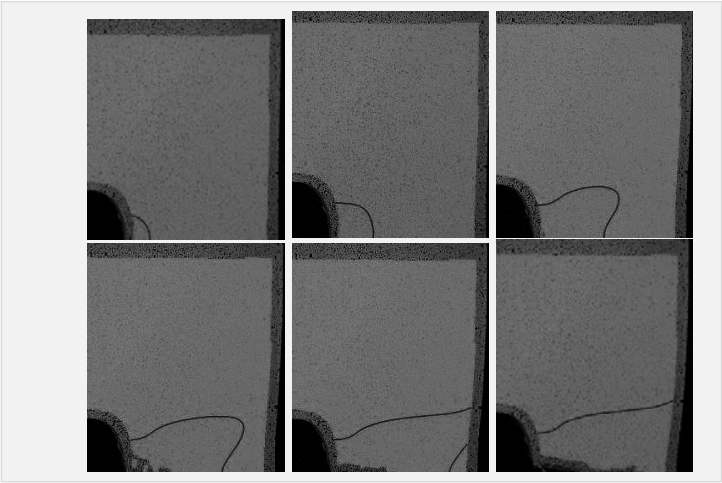

Figure 1 - *Evolution of the zone of the postcritical deformation during tension test*

#140 Weldability of old mild steels in maintenance of historical steel structures

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Abstract Although many structures made of old mild steel erected during the period between 1890 and 1940 are still under load after decades of service, there is usually no need to replace them. When assessing these existing steel structures to be able to decide on necessary rehabilitation and reinforcement measures engineers requires information about the mechanical as well as the technological properties of the material. The weldability of old mild steels is limited and only feasible under specific conditions. If for structural reasons welding is preferred instead of the use of bolts, the characteristics of the steels have to be considered. These include the concentrations of impurities in the zones of segregation and the tendency to embrittlement by nitrogen-induced ageing of steels refined by air (e.g. Thomas steel).

In the case of fillet welds at the surface of a member systematic investigations on the weldability of old mild steels, the selection and adjustment of the welding processes have been carried out. It is essential for an adequate welding to reduce the introduced line energy to minimize the weld penetration in the base material and to avoid the melting of the segregation. A welding procedure suitable for use on construction sites is the manual metal arc welding with basic-coated stick electrodes. The filler material reduces the tramp elements and provides ductile welds. In the corresponding paper, experimental and analytical studies of the weldability of old mild steels are presented. Extensive material analyses to determine the mechanical and the technological properties of the material are an essential part of the investigations. Particularly, the increased impurities of phosphorus, sulfur, nitrogen and also oxygen in the segregation zones as well as the distinctive non-metallic inclusions complicate to produce load-bearing butt welds (see Figure 1). In the context of a research project the applicability of currently available filler materials for welding such materials are analyzed. Supported by involved industrial partners, a welding electrode adapted to the characteristics of old steels will be developed.

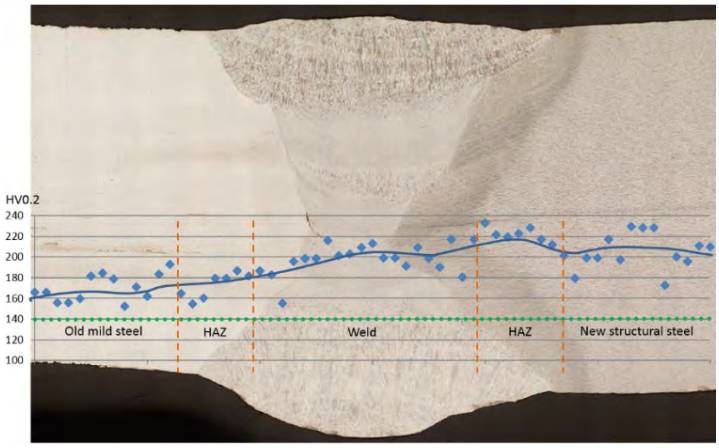

***Figure 1** – Hardness measurement at a microsection of an X-shaped butt weld*

#141 The brittle fracture behaviour of old mild steels

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Abstract In addition to determining the level of the structural safety, the safety against brittle failure is essential in the assessment of existing steel structures of the 19th and early 20th Century and for the decision on necessary rehabilitation and reinforcement measures. The assessment methods in EN 1993-1-10 to avoid brittle failure were developed for welded structures made of current steel grades with high toughness. This method is not suitable for old mild steel structures with riveted and bolted connections. On the one hand, notch effects and residual stress states differ in welded and riveted structures. On the other hand, the material properties of old mild steels (Thomas-, Bessemer- or Siemens-Martin-Steel) are characterized by considerably larger scatter, particularly due to the inhomogeneous distribution of tramp elements and higher contents of non-metallic inclusions. Due to the often much lower impact toughness of mild steel, structures are often rejected by engineers with insufficient experience with old steels because they assume "material embrittlement due to aging".

In the corresponding paper, experimental, analytical and numerical studies of the brittle fracture behaviour of structures with holes made of old mild steel are presented. Extensive material analyses to determine the fracture toughness in the brittle-ductile transition region according to the Master Curve concept (ASTM E1921) have been an essential part of the investigations. The evaluations confirm that different grades of old steels can be defined depending on the manufacturing process. To analyse the influence of punching the holes (see Figure 1) on the brittle fracture behaviour of old mild steels, structural examinations and micro hardness measurements have been performed. Based on an extensive analysis of typical construction details of existing structural steelwork, fracture mechanical finite element calculations of connections of angle profiles have been performed to determine their toughness requirements. The obtained results of the stress intensity factor are revised for further use by modification of known solutions from the specialized literature.

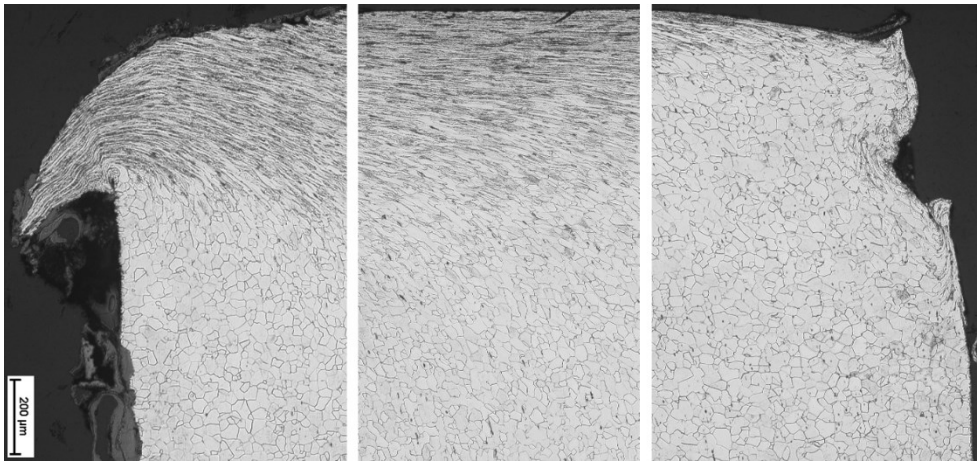

***Figure 1** – Micrograph of the punched edge of a rivet hole*

#142 Improvement of the fatigue crack growth resistance in long term operated steel strengthened with CFRP patches

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Abstract

The maintenance of the old steel structures is one of the main challenges in engineering practice – mainly due to the lack of the experimental data performed for existing old steel structures erected at the turn of the 19th and 20th centuries. In this paper the fatigue crack growth behavior in structural components from the old 19th (and early 20th) centuries structures (e.g. bridges) has been investigated. The delivered material for investigation was extracted from a beam made from puddled iron and mild rimmed steel, commonly used 100 years ago. The obtained results from several ancient railway metallic bridges (located in Lower Silesia, Poland) have shown the presence of microstructural degradation processes in puddled iron. The mentioned processes supported the brittleness of this type of materials. It has been confirmed in author's experimental works, that the fatigue crack growth rate in this ancient type of steel is higher than in its modern equivalent. One of the fundamental engineering task is the problem of the extension of the precritical fatigue crack growth in such a type of steel. One of the promising approach is hybrid approach (experimental-numerical) based on the additional energy dissipation mechanisms in fatigue crack growth process. One of the successful strengthening method is the CFRP (Composite Fiber Reinforced Polymer) patching along the fatigue crack paths. The presented approach has been studied and discussed in this paper on the background of the numerical and experimental data. As it was expected, the proposed strengthening method is efficient and promising in case of the "immediate" repairs of critical members with cracks.

#143 The study of evolution of physical and mechanical properties of metals under gigacycle fatigue.

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Abstract Today we need to ensure the safe operation of the resource mechanisms and structures for high production efficiency. Such as bridges, railways, parts of cars and planes. Sometimes secure the operation of the objects reached at least 1010 cycles. To research a material during 10 cycles it is required a lot of time. Ultrasonic test machine is used for getting the results during the short period of time [1]. The work include experimental investigation of evolution of Armco-iron in very high cycle fatigue using ultrasonic testing machine SHIMADZU USF-200 with loading frequency 20kHz and theoretical investigation of features of defect ensemble defects evolution under low cyclic loading. The results obtained by authors previously showed that fatigue loading leads to accumulation of porosity in the samples of Armco-iron and a corresponding decrease of their elastic properties [2]. It is allows propose the model of volume defect evolution which describe peculiar properties damage-fracture transition under VHCF. Based on analysis of obtained constitutive equations the possibility of fatigue crack initiation was shown. The model allows describe two types of fracture mechanisms the pores initiation and PSB localization, the last was shown by C. Bathias et all. [4].

It is necessary to separate different types of fracture based on posteriori investigation of tested specimen and in-situ monitoring test process using nondestructive control methods. The main problem in this area of fatigue is prediction of fracture because usual non-destructive tests non-applicable with ultrasonic technique.

The magnetic and electrical methods were developed for analyze the peculiar properties of micro damages accumulation. The technique allows us receive the time dependence of the signal from the magnetic detector and the time dependence of the potential drop from the sample during the test. The both methods shows continuous increasing of signal and the final stage of the experiment methods illustrate jumpwise increasing of the data that indicates the fracture of specimen.

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#145 Analytical models of the S-N curve based on the hardness of the material

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Abstract Fatigue life must be verified at all times when designing elements of machines subjected to loads variable in time. To make the calculations possible, the S-N characteristics for the material or construction element (depending on the calculation model employed) must be obtained. Such data are not available at the design and construction stage, when the designed element is merely a concept. Due to this, analytical models are used for estimating the S-N fatigue curve. Since these methods bear significant error, hybrid models based on experimental data from hardness measurements were developed. Such evaluation is easy to perform, quick, and, most importantly, is a non-destructive examination. The paper presents two models for evaluating high-cycle fatigue characteristics, one of which is a own model. Both of these approaches are based on hardness measurement, and employ the relationship between hardness and tensile strength & fatigue limit. It must be pointed that recommendations of standards for construction materials specify minimum values, or a range of acceptable values for tensile strength or yield stress. This is frequently not enough due to significant dispersion in the actual value of the feature of our interest. The described models were verified on experimental data for several construction materials, i.e. S235JR, S355J2+C, C45+C, 42CrMo4, 1.4301 steel and AW-6063 T6 aluminum alloy. Tests were performed on smooth samples, and - for two materials - on notched samples. Moreover, literature data were also used for expanding the verification performed. The characteristics obtained indicate that the estimation of fatigue life for construction steel may be deemed as satisfactory. For the example in Fig. 1 a curve for S355J2+C steel was presented. For the aluminum alloys and stainless steel, on the other hand, the estimation error is significant.

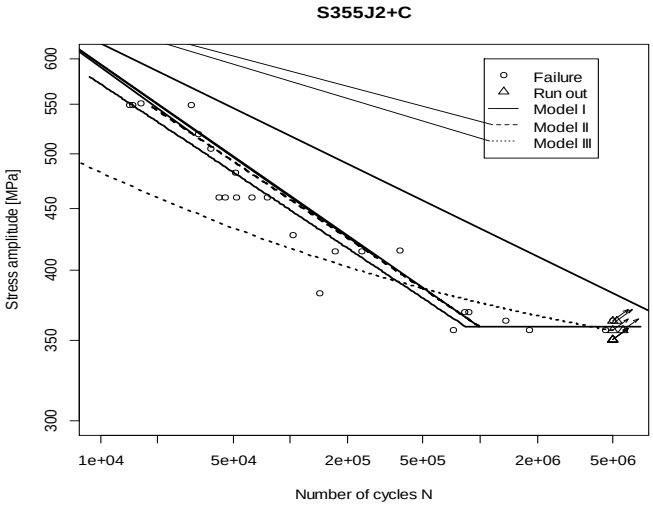

Figure 1 – *S-N curves for S355J2+C steel acc. standard test method (model I) and analytical methods (model II – own method, model III - Bandara et al.)*

#146 Estimation of the impact stress gradient in the range of size effect

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Abstract The size effect describes the dependence of strength properties of material or construction element on the object size. This requires taking it into consideration in engineering practice. It originates from inaccuracy of the scaling process, since it is physically impossible to change all properties of the object at a fixed level (i.e. material structure, changes to outer surface). Proper interpretation of the size effect is possible to systematic arrangement of its origin, classified in three areas: statistical, geometric and technological. The proposed conditions of own tests allowed for verification of the geometrical size effect, which was analyzed in terms of stress gradient in the scope of stress concentration (notched specimens) or load type (bending, torsion). The analytical model describing this effect is based on highly stressed volume $V_{n\%}$, in which probability of the development of fatigue cracking is higher. $V_{n\%}$ parameter is defined as the volume of material subjected to at least n% of maximum stress. The method determines fatigue strength depending on the specimen shape and the type of load applied (Fig. 1).

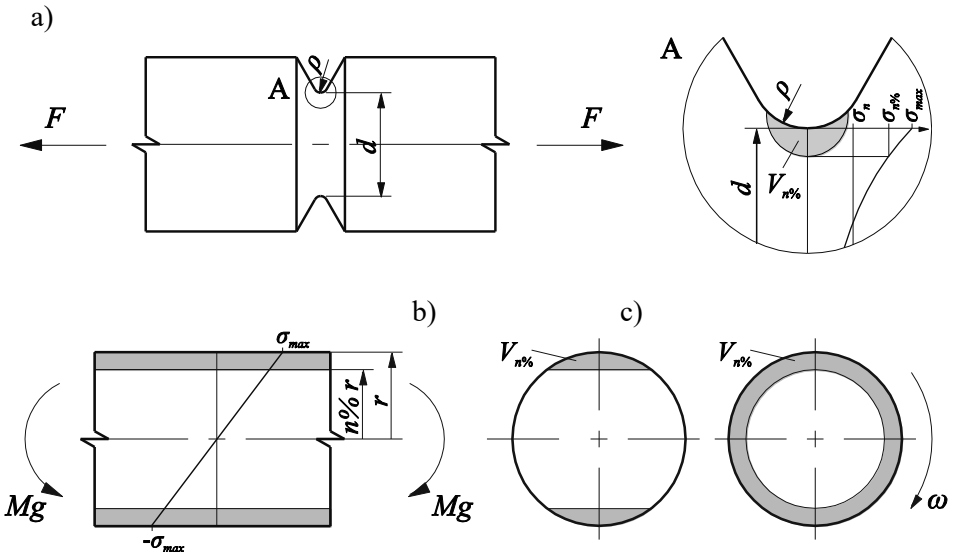

***Figure 1** – Stress distribution and highly stressed volume in the specimen during: a) axial load (notched spemcien), b) pure bending, c) rotary bending*

The aim of the paper is to estimate the impact of size effect for high-cycle fatigue on standard specimen and mini specimen made of 1.4301 stainless steel. This material features sensitivity to statistical size effect (randomly distributed places at which initiation and development of fatigue cracks is possible). The variability of test conditions included specimen shape and stress type (axial tension, compression; four-point bending).

#147 Structural Health Monitoring on an Unmanned Aerial Vehicle Wing's Beam Based on Fiber Bragg Gratings and Pattern Recognition Techniques

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Abstract Composite materials have been extensively used in new aircraft airframes, taking advantage of their minimal corrosion sensibility, much better fatigue behavior, and higher specific mechanical properties compared to metallic materials. By contrast, composites represent a difficulty for damage detection, which is a critical matter in the aerospace industry, a business based on safety and reliability. Finding and assessing damages on this kind of materials is a difficult task since their main failure mode occurs inside the material and is not visible, additionally most nondestructive testing methods are not effective on composites. A novel technique for Structural Health Monitoring (SHM) based on the use of Fiber Bragg Gratings (FBGs) to measure strains, a wireless local area network for data transmission to a processing station on ground, and the later usage of classification and pattern recognition techniques to perform an Optimal Baseline Selection (OBS), is presented in this paper.

On this work, the main beam of an Unmanned Aerial Vehicle´s (UAV) wing was manufactured with carbon fiber reinforced polymer with embedded FBGs. Different operational tests were performed, varying the beam's stiffness by attaching a reinforcement as a positive damage. Sensor's measurements were acquired with a miniaturized, high-speed FBG interrogator system, connected to a mini on board computer. These data were real-time transmitted to a ground station via wireless network and subsequently processed by using an OBS methodology based on Self-Organizing Maps (SOM) and Local Density-based simultaneously Two-level Clustering (DS2L-SOM). Such methodology allows to classify the operational conditions and create multiple baselines related to each load condition. In this way, it is possible to uncouple the damage effects from the influence of operational conditions. Finally, a Principal Component Analysis (PCA) was performed to calculate different damage indices and thresholds. This is how the damage assessment was achieved.

The tests performed proved the system's capability to detect damage on the structure by distinguishing changes on the main beam's strain field of its pristine and damaged conditions. The implementation of this SHM methodology leads to perform real-time damage detection on aerospace complex structures made of composite materials.

#149 Hydrogen Induced Damage in Heavily Cold-Drawn Wires of Lean Duplex Stainless Steel

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Abstract: The paper addresses the sensitivity to hydrogen embrittlement of heavily cold-drawn wires made of the new generation of lower alloyed duplex stainless steels, often referred to as lean duplex grades. It also includes comparisons with similar data corresponding to eutectoid and duplex stainless steels. For this purpose, fracture tests were carried out with wires in the as-received condition and fatigue-precracked, in air and FIP-solution of ammonium thiocyanate, both under constant and increasing load at low strain rate. Microstructure and fracture surface observations by scanning electron microscopy have been used for the analysis of hydrogen-assisted cracking and collapse mechanisms of the studied wires (Figure 1).

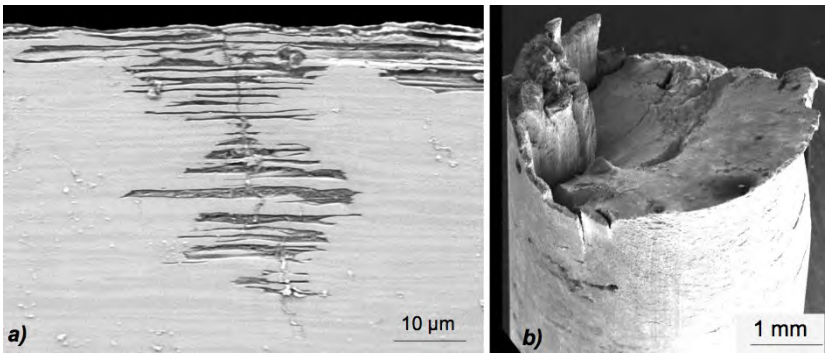

Figure 1 – *Hydrogen-assisted failure in heavily cold-drawn lean duplex stainless steel wire: a) superficial depassivation and subcritical cracking paths; b) over-all view of rupture*

The effect of hydrogen-assisted embrittlement on the damage tolerance of lean duplex steels was assessed regarding two limits of damage tolerance. These were found to accurately approximate the failure behavior of cold-drawn wires of eutectoid and duplex steels.

The paper shows that in the standard FIP test, the lifetime of the lean duplex wire exceeds that of the eutectoid wire by more than 10 times. The hydrogen up-take makes a thorough change in the fracture micromechanisms from ductile growth and coalescence of microvoids to mixed trans and intergranular cracking. The hydrogen induced damage extends as a subcritical transverse crack that starts at the wire surface and grows assisted by the medium and by the applied load, up to a critical size when it axially deflects and the plastic collapse of the resistant ligament occurs.

When fatigue-precracked lean duplex wire is subjected to constant or increasing load in FIP solution, it has a similar behavior as the duplex wire, but at higher cracking rates. In both cases the front of the fatigue crack is only the axial cracking initiator and does not modify the plastic collapse of the resistant ligament. Even so, the lifetime of the fatigue-precracked lean duplex wire doubles that of a eutectoid wire of equal precrack size.

#150 Moisture absorption effect on the stress distribution of the cross-ply laminates with transverse matrix cracks

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Abstract The purpose of this paper is to investigate the moisture absorption effect on the stress distribution of the cross-ply laminates with transverse matrix cracks. Two analytical models were used to evaluate the stress distribution, Shear Lag and the variational approach. The results show that a complete parabolic variation of displacement gives a good approximation of the stress distribution compared to the finite element analysis. Furthermore, the cracked cross ply laminate is submitted different temperature and moisture concentration distribution. The predicted model shows that moisture absorption has a significant effect on the stress distribution especially at the higher crack density.

#151 Fracture toughness of fibre-reinforced concrete determined by means of numerical analysis

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Abstract As it is well-known, the addition of fibres to concrete mix (Fibre Reinforced Concrete, FRC), can produce a positive effect on all the material mechanical properties, and particularly on its tensile strength, ductility, workability and shrinkage. As the fibre-reinforced material shows a larger toughness, the presence of fibres especially improves those properties that are typically related to the post-cracking behaviour. Several studies were aimed to determine the proper volumetric percentages, aspect ratios and types of fibres (steel, synthetic, or a hybrid mix), which can even lead to the use of fibre as partial replacement of traditional reinforcement in several structural applications.

Within this research field, in this work an experimental campaign on FRC specimens with randomly distributed micro-synthetic polypropylene fibrillated fibres is considered. The tests concern single-notched beams under three-point bending, where the fibre content is varied.

Firstly, this experimental testing is numerically modelled through non-linear finite element analyses, where a proper constitutive law for fibre-reinforced concrete is implemented [1,2]. The model, formulated in terms of secant stiffness matrix, is obtained by imposing equilibrium and compatibility conditions both in uncracked and cracked material. In this way, all the fundamental resistant contributions offered by both fibres and concrete are properly taken into account so reproducing the structural material behaviour until failure. The parameters governing tension-softening behaviour are properly calibrated on the basis of the above experimental data (load-CMOD behaviour). Then, the numerical load-deflection curves are employed to determine fracture toughness, for different values of fibre content, according to the RILEM recommendation. Finally, such fracture toughness values are compared to those obtained by employing the modified two-parameter model [3].

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#152 Fatigue reliability analysis of a turbine disc under multi-source uncertainties

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Abstract: As one of fatigue critical parts of an aero engine, the life and reliability research on the high pressure turbine disc plays an important role in improving the engine structural integrity. At present, the loads, material properties and working environments are usually viewed as deterministic inputs in structural design and fatigue life evaluation of the turbine disc. Obviously, for the turbine disc which needs take a long time under high temperatures to withstand complex and variable loads, the above factors have shown high uncertainty, and the influence of this multi-source uncertainties on the structural response of the turbine disc cannot be ignored. According to this, the rotation speeds of turbine disc under different flight missions and material properties of turbine disc at different temperatures are treated as random variables, and sample them independently by using the Latin hypercube sampling. In order to consider the mechanical behavior of GH4169 under high temperatures, material response variability is modeled by using the Chaboche constitutive models. In addition, in order to truly reflect the structural characteristics of the turbine disk with complex shape, the inhomogeneity of its constituent material is also considered through the finite element simulation platform in this paper. According to the stochastic modeling of the turbine disc combined with the above analysis, finite element (FE) analysis is performed 10^3 times for fatigue reliability analysis. Using the Fatemi-Socie damage criterion, fatigue reliability analysis of the turbine disc under multi-source uncertainties is carried out for different flight missions.

Key words : multi-source uncertainties, fatigue reliability, turbine disc, finite element analysis, Fatemi-Socie criterion

#153 A new strain energy gradient-based model for LCF life prediction of turbine discs

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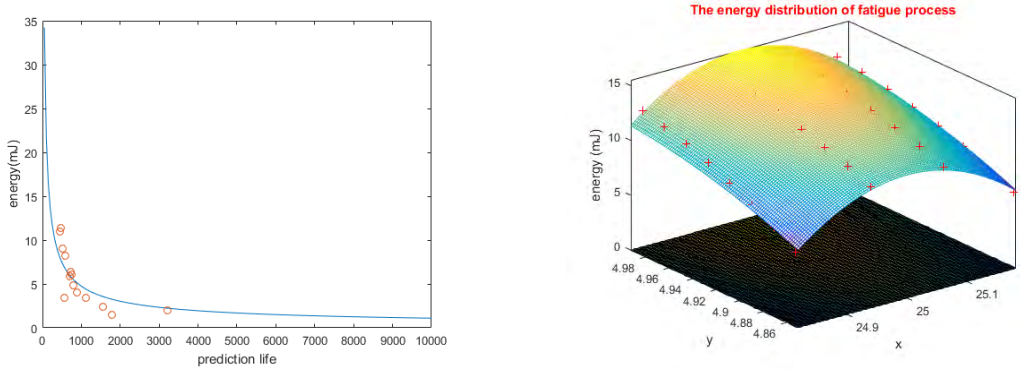
Abstract: Turbine disc as the fracture critical component of aircraft engines, which installs the blades to transmit power. During engine's operation, turbine disc is subjected to high temperature, high pressure and high rotational speed. With continuous raising of the thrust-weight ratio and gas temperature, low cycle fatigue (LCF) failure is one of main failure modes for engine hot section components. More accurate life prediction of turbine disc under complex stress state and working environment has important theoretical significance and application value. For this reason, this paper will follow the assumption of fatigue process proposed by predecessors, considering the energy gradient concept with the energy dissipation principle to propose a new LCF life prediction model which is suitable for complex geometry and working environment. In this paper, assuming that the process of crack initiation and propagation in a LCF regime can be described by the cumulative process of strain energy which contributes to fatigue damage accumulation. In order to avoid the complex crack initiation and propagation process, the relationship between energy dissipation in the fatigue process zone and the LCF life is investigated. In this model, the energy parameters are weighted based on the energy gradient in the fatigue process zone. Using experimental data of GH4169 alloy under strain control at 650℃, a good agreement is noted between the predicted and experimental results. Moreover, model predictions by the proposed one have shown higher accuracy than that of existed plastic strain energy density model and total strain energy density model. Finally, an application of this proposed energy model to a turbine disc life prediction using finite element method is presented.



(a) (b)

Figure 1 *(a) Relationship between energy and prediction life (b) Energy distribution of fatigue process zone of GH4169 alloy at 650℃*

#158 Investigations on crack propagation in wheelset axles under rotating bending and mixed mode loading

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Abstract Wheelset axles are regularly non-destructively inspected in defined intervals in order to prevent unexpected failures and to assure a safe life. An assessment of appropriate inspection intervals can be made by using a reliable computed remaining lifetime prediction. However, the existing analytical models for calculating the remaining lifetime of thick-walled shaft structures are still under research and do not consider different crucial influencing factors, which will be addressed within this paper.

Wheelset axles are exposed a rotating bending during operation. Due to different load scenarios a variable amplitude loading occurs. Moreover, press-fit stresses are superimposed, i.e. the *R*-ratio shifts from -1 to higher values. Therefore, crack growth curves have been determined for different *R*-ratios and statistically evaluated. Moreover, a test-rig for shouldered solid shafts has been developed. For the experimental investigations two types of specimens have been used. Thereby, the design of the specimens has been varied, i.e. different stress concentration factors as well as a press-fit are realized. In the section planes with maximum bending stresses a notch has been inserted with a depth of 0.5 mm and an aspect ratio of 0.8 using a pico-second laser. Within this paper, the influence of the different geometrical details on the development of the crack geometry and the residual lifetime will be discussed and accompanied with numerical simulations results.

Moreover, at special wheel-rail-situations, for example at a track switch, additional stresses due to torsional loads occur. These stresses can affect the crack propagation in wheelset axles during the operation, too. Thus, this paper will also give a summary of the current results in experimental tests and simulations of crack growth under overlapping bending and torsional loading.

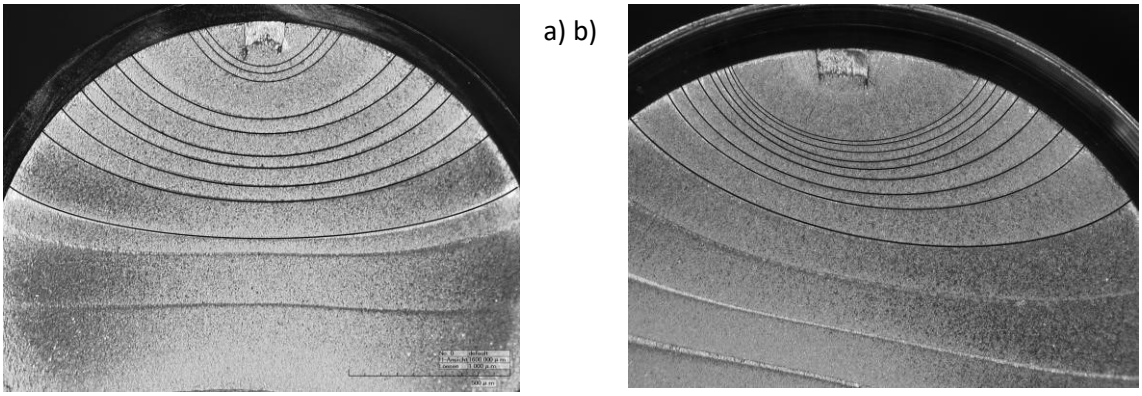

***Figure 1** - Development of the crack geometry depending on the stress concentration factor of the transition radius with a) K_t = 1.1 and b) K_t = 1.32*

Funded by the Karl-Vossloh foundation.

#159 Numerical studies of the residual lifetime of power plant components based on experimental results at elevated temperatures

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Abstract In the future, the energy supply will strongly fluctuate, which results in more frequently load cycles. For this reason, it is necessary to analyze fatigue crack growth under the aspect of reasonable load cases in relevant power plant components.

Therefore, numerical three-dimensional fatigue crack growth simulations for different power plant components have been performed using FRANC3D taking temperature transients and pressure loads as well as different relevant crack positions into account. The results show that thermal loadings have a much higher influence on stresses and as a consequence on stress intensity factors than mechanical loadings. Hence, cracks under transient thermal loading will grow faster than under constant temperature and pressure conditions.

In order to quantify the residual lifetime, temperature-dependent fatigue crack growth curves were experimentally determined as a function of the *R*-ratio. Therefore, experiments with constant temperatures between room temperature and 600°C have been performed using C(T)-specimens cut of a decommissioned high-pressure bypass station made of the ferriticmartensitic steel X20CrMoV12-1. The investigations show that crack growth rates rise in the PARIS regime under higher temperatures. The data were finally used to extract $a(N)$-curves from numerical results in FRANC3D. The results indicate that thermal loading leads e.g. in a sphere molded body to a number of cycles to failure that is a thousand times smaller than only under mechanical loading. Moreover, the investigations show that different power plant components are different endangered for a sudden failure, because of their various load cases. For that reason lifetime analysis under elevated temperature is important to define inspection intervals for each relevant component.

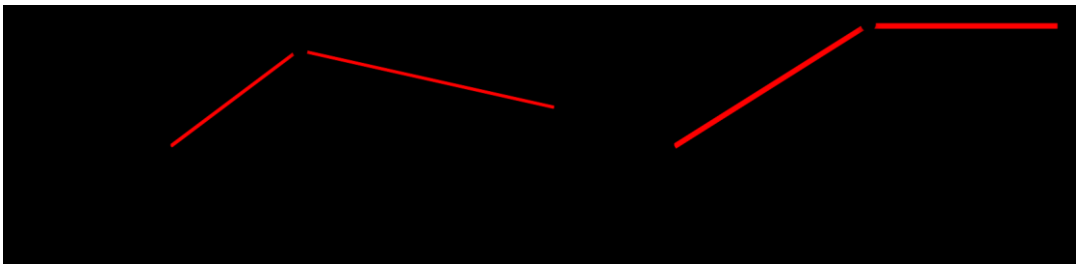

Figure 1 – *Stress intensity factors due to a) thermal and b) mechanical loading*

Joint project THERRI funded by the Ministry of Economic Affairs and Energy.

#160 Fatigue Life Evaluation of Critical Details of the Hercílio Luz Suspension Bridge

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Abstract The Hercílio Luz Suspension Bridge, which was built in 1926, was closed to traffic in 1991 due to high corrosion levels and deterioration of critical structural elements [1]. A complete rehabilitation project was developed for the bridge which includes the replacement of the compromised members and strengthening of the foundations. Throughout the rehabilitation process an auxiliary structure is being employed to support the central span of 340 m (1115 ft). In this paper, a fatigue assessment is carried out using the fatigue load models 3 and 4 indicated by Eurocode EN 1991-2 [2] to obtain the calculated stress ranges for the critical members of the bridge, as well as the simplified equivalent stress ranges and fatigue damage accumulation methods for the fatigue safety verification defined by Eurocode EN 1993-2 [3] and Eurocode EN 1993-1-9 [4]. A parallel fatigue assessment was performed using the American Association of State and Highway Transportation Officials (AASHTO) Manual for Bridge Evaluation (MBE), 2nd Edition [5]. Finally, a comparison is made between the methods and results obtained using the European and American codes.

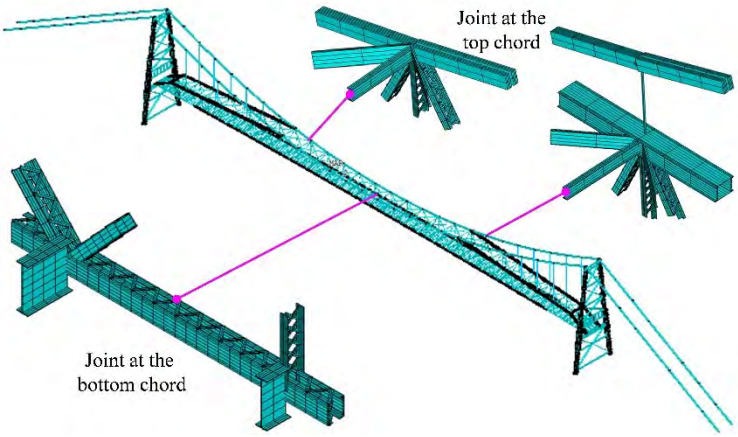

***Figure 1** – Global structural model and local models of the Hercílio Luz Suspension Bridge.*

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#161 Static and fatigue behaviour of Sikadur®-30 and Sikadur®-52 structural resins/adhesives

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Abstract

This paper has as main theme the characterization of the monotonic and fatigue behaviour of structural adhesives/resins used in repairing and maintaining of old metallic bridges. This study aims essentially at the mechanical characterization of structural adhesives/resins, such as, Sikadur®-30 and Sikadur®-52, used to fill the gap between the bolt and plates of the metallic connection.
The monotonic behaviour will be analysed through an experimental campaign whose objective is obtaining the mechanical properties, such as the Young modulus, Poisson ratio as well as the tensile, compression, shear and flexure strength. Additionally, the steel-to-steel bond strength of these resins/adhesives will also be studied.
Concerning the fatigue behaviour, experimental tests under uniaxial loading will be performed following the procedure referred in the ASTM D7791-12 standard to obtain the cyclic elastoplastic fatigue behaviour of the structural resins/adhesives. The fatigue tests will be made using the uniaxial loading systems with tension and compression capabilities. The fatigue properties can vary with specimen depth and test frequency. The influence of these parameters will be taken in consideration in this study. Test frequency can be 1-25Hz, but it is recommended that a frequency of 5 Hz or less be used.
Fatigue behaviour results of structural resins/adhesives are important for use in advanced numerical models of fatigue strength prediction of resin-injected bolted connections.

#162 Failure Analysis Of Composite Repaired Pipelines With An Inclined Crack Under Static Internal Pressure

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Abstract. The aim of this work is to use the glass fiber reinforced polymer, GFRP, composite repair to reduce the fracture parameter of stationary inclined crack in steel pipelines under internal static pressure. The effect of the stacking layer sequence of bonded composite repair on the variation of the *J*-integral value of that crack are described in the present work. The three dimensions finite element method, 3-D FEM, is used in this investigation.

The composite repair has not effect on the crack path which emanate from inclined stationary crack in steel pipe. Furthermore, the pipe with composite repair need a higher pressure value to initiate the crack from stationary crack in pipe than pipe without composite repair. The composite repair reduce the value of *J*-integral of stationary crack in steel pipe and this values change by changing the stacking layer sequence of composite repair.

#163 Surface factor assessment in HCF for steels by means of empirical and non destructive techniques

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Abstract The fatigue limit value in steels is strongly influenced by many factors, among them the surface finish.
The fatigue limit decreases with increasing the surface roughness, referring to standard grinded specimen.
Technical literature provides an empirical correction factor, named surface factor, to be used if surface roughness is different from standard specimen conditions. This factor is traditionally lower than 1 and it reduces the fatigue limit value corresponding to the material in standard conditions.
This coefficient is obtained from literature graphs and it can be identified by means of two parameters: materials ultimate tensile strength and surface finish *Ra*.
Aim of the present paper is to evaluate the effectiveness of fast procedures to assess the surface factor.
The reference is the Murakami model, which estimates the fatigue limit by means of roughness parameters other than *Ra*.
In the present paper the fatigue limit estimations on specimens with sanded *Ra* obtained by means other empirical destructive and non destructive methods estimations are compared.
Experimental testing was carried out on a structural steel specimens by means of axial alternate fatigue testing with two different surface roughness.
The results obtained referring to Murakami model were compared with those obtained by means of thermographic methods and Staircase method.
The Murakami model results to be easy to use and non destructive.
The corresponding fatigue limit estimations match with thermographic estimation above all when surface roughness is elevated.

#166 Estimation of thickness scale in water pipe by artificial neural networks and thermographic model

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Abstract The continuous operation of nuclear power plants can accelerate the fatigue phenomena of their metal structures by producing cracks. Nondestructive testing and preventive maintenance are therefore required in order to avoid accidents that will have serious consequences for the environment. In the context of non-destructive testing of water pipes by infrared thermography. We will present in this work a simulation by the 3D finite element method, the scale presence in a steel water pipe. We will study the effect of the geometric parameters of the pipe like the thickness and diameter on the scale detection. After studying the detection, we will characterize the tartar layer by studying the effect of its thickness on the closed pipe thermal response. Then we propose a model allowing estimating the scale thickness from the surface temperature of the controlled pipe. Finally, we will use the technique of artificial neural networks to increase the accuracy of the thickness scale estimation of the hot water distribution networks.

Key words: Infrared thermography, 3D finite element method, scale thickness, artificial neural networks.

#167 Assessment of fatigue limits in historical welded railway bridges in Poland

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Abstract The fatigue limit assessment procedure is one of the most essential for global resistance and durability estimation of welded bridges in operation for a longer time. During radiographic testing of early welded railway bridges there was ascertained a bad condition of welded butt splices including internal cracks as well. Radiographic tests were carried out on welded butt splices in the main girders of 155 bridges, including 125 plate girder and 30 truss bridges. Cracks were discovered in 34 bridges (21.9 %) on 437 radiographs. The number represents 2.8 % of the weld segments tested, from a total of 15,875 radiographs of which 10,507 refer to tension members.

The structural-stress analysis given in the paper was limited to the eight oldest welded railway bridges in Poland constructed from 1935-1938. The spans of the bridges range from 9.00 to 32.40 m. They were tested from 1 to 4 times over the years 1958 – 1984. A total of 670 photographs were taken of the butt joints. The quality levels in accordance with the requirements of EN ISO 5817 were assessed with 69.3 % of the butt weld segments tested featuring welded imperfections of quality level D and higher. On 124 radiographs, cracks in the welds were found. Multiple testing did not uncover any further increase in the existing cracks.

Fatigue testing of butt welds with cracks and strength analysis of bridge connections were undertaken which allowed for fatigue assessment of the bridges. The regression line and the results of fatigue tests on eighteen specimens with welded butt splices showing internal cracks are given in Fig. 1. The average infinite life fatigue strength value was calculated from the regression line equation in a logarithmic scale for $2 \cdot 10^6$ cycles and is equal to $Z_{rj} = 89.9$ MPa. This value is 28 % of the yield strength for the steel tested $f_y = 320$ MPa and each time it is larger than the service stress, whose maximum value is $\sigma_{ser,max} = 74.4$ MPa. This means that the initiated crack stress is lower than the stress necessary for the cracks to increase.

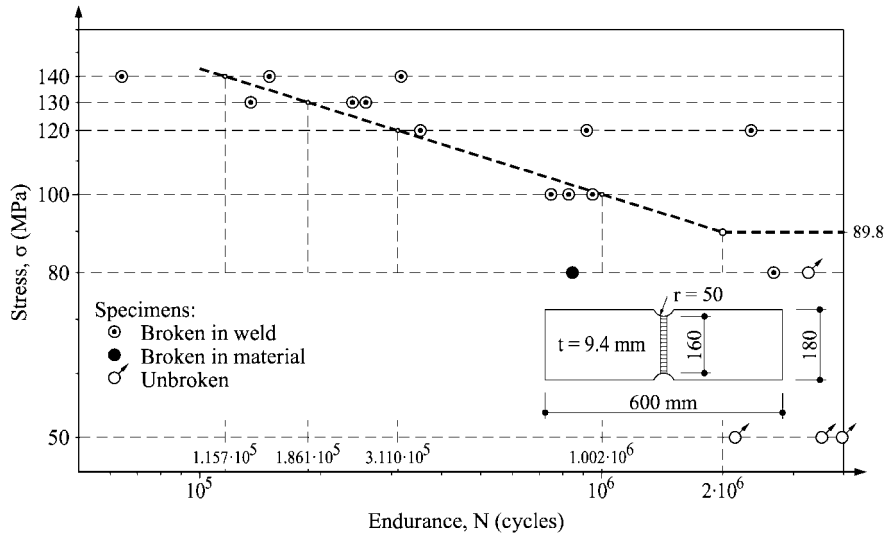

Figure 1 - *Linear regression and fatigue test results on 18 specimens.*

#168 Toughness tests on steels from old railway bridges

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Abstract Toughness of steel describes its ability to absorb energy and deform plastically without fracturing. Modern steels show the high toughness values required for welded structures; this is not the case, however, for steels in old railway bridges which have had a lengthy period of operation. So-called ageing effects lower the toughness of steel over time. The results of impact energy (Charpy) measurement on steels from five railway bridges built from 1875 to 1930 are presented. Four bridges were manufactured from mild steel (low carbon) and one from medium carbon steel. Data for the bridges, the chemical and tensile properties of their steels and the results of the impact energy tests are also given. The impact tests were conducted on naturally-aged, normalized and fully annealed Charpy-V specimens. The ductile-to-brittle transition temperature was assessed. The average values of the impact notch tests for naturally-aged specimens from 5 bridges are shown in Fig. 1.

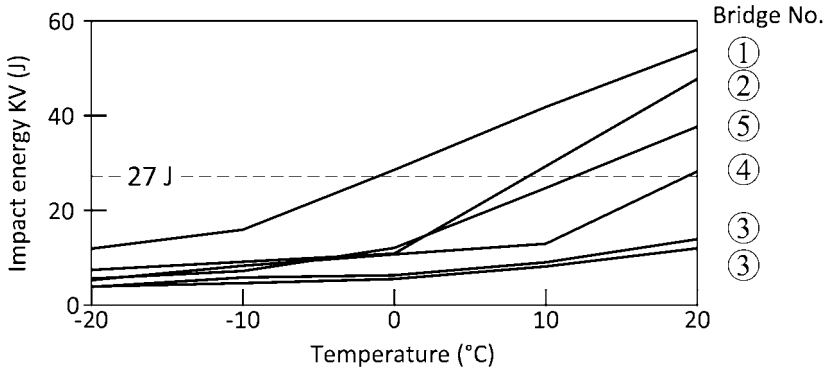

Figure 1 *– The average results of the impact tests for naturally aged steels.*

Low values of impact toughness at minus temperatures are characteristic for old riveted steel structures with a long period of service. On one bridge (No. 3 - 130 years in operation) they are low even at plus temperatures. This is a very dangerous phenomenon in terms of the possibility for brittle fracture in winter conditions. However, it is considered that the modern impact toughness requirements for welded steel structures with thick plates are not strict enough for riveted built-up sections with relatively thin plates.

To estimate the effect of natural ageing on the steels, tests were carried out on specimens treated by normalized annealing and, additionally for bridge No. 3, by full annealing. The purpose of normalizing is to obtain properties of the material similar to those at the time of delivery (the bridge construction). The normalization increased the impact energy of the steels considerably and for bridges Nos. 2 - 5 it was assessed to be in accordance with modern requirements.

Material tests on the steel in old bridge structures are usually limited to verifying its chemical and tensile properties i.e. an evaluation of the type of steel, calculations of its strength properties and determination of yield strength as basic parameters. In the paper, a simulation of initial material properties by normalizing is used as the basis for comparing the changes in material properties.

#169 Development of 2D analytical model for the prediction of directivity pattern of transducers in generation of guided wave modes

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Abstract The guided waves are extensively used in the nondestructive testing (NDT) and structure health monitoring (SHM) of the large and complex structures. It enables to detect the defects up to few meters away from the transducers. However, the defects could occur at longer distances. In order to cover the test area of interest for the estimation of defects and to find the exact position of the transducers to be glued/ embedded, the directivity pattern of transducers must be known. The directivity patterns depict about the coverage area and wave intensity in order to decide the excitation frequency and position of the transducer on the objects to be tested. In addition, it facilitates to decide the optimum number of transducers required for testing the whole structure which in turn reduces the overall cost of the entire system.

The aim of the presented work is to develop the 2D analytical model for the estimation of directivity patterns of the transducers at various frequencies. The model was developed using the Huygens's principle of wave propagation distances with considering the known dispersive characteristics of guided wave modes in the medium. The model will work to plot the directivity pattern at any distance, excitation frequency with any configuration and shape of the transducer. The methodology behind the modeling is to considering the volume of transmitting zone as a series of points and calculating the magnitude and phase of distance vectors of each point source to the arbitrary receiving elements. After calculating and integrating the distance vectors between point sources to all receiving points, the B-scans of different modes are generated along the receiving zone. The distance diffraction factor, direction factor and medium attenuation are also considered. The directivity patterns are then plotted by calculating the normalized peak-to-peak amplitudes of the signal components (A-scans) versus the angular position of the wave modes.

In order to test the model, the directivity patterns of P1-type macro-fiber composite (MFC) transducer in the generation of fundamental wave modes (the A0, S0 and SH0) at 300 mm from the center of MFC were obtained at 80 kHz excitation frequency by considering the 2 mm Al plate as a medium. It is observed from the resulting directivity patterns that *out-of-plane* mode (the A0) has a narrower pattern as compared to the S0 mode. This recommends increasing the number of MFC transducers for testing the larger area using A0 wave modes. It was also observed that shear horizontal (SH0) mode, instead of showing its directional behaviour along the perpendicular direction of propagation, are dominant at 45º, 135º, 225º and 315º. Therefore, they are not suitable to be used for the defect estimation in the direction of propagation. This is also observed that changing the excitation frequency completely changes the shape of directivity patterns.

The results were validated using finite element (FE) simulations performed in *ANSYS* and further verified by the experimental analysis using low-frequency ultrasonic measurement system *ULTRALAB,* developed by Ultrasound Research Institute, Kaunas University of Technology. The proposed analytical model will not only facilitate to decide the position and number of transducers but also leads to choosing the specific transducer and wave modes for the inspection of defects.

#170 An Optimized RBF Analysis of an Isotropic Mindlin Plate in Bending

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Abstract

This study focuses on the numerical analysis of an isotropic plate under a uniform distributed load. The problem is solved considering the Reissner-Mindlin plate deformation theory combined with a Radial Basis Function (RBF) meshless method. Thus, in this work, the RBF meshless method formulation for the analysis of thick isotropic plates assuming a first order shear deformation theory is shown with detail. Additionally, the essential boundary conditions, material properties and geometrical characteristics of the model are fully presented. Based on mechanics of the laminated plates, the nonzero laminate stiffnesses are determined through equations of motion in terms of displacements for homogeneous laminates.

The transverse displacement results are evaluated for various thickness values where the plate is simply supported in all edges. Additionally, the shape parameter governing the RBF formulation is optimized using several mesh densities. The obtained numerical results are compared to the exact analytical solution available in the literature. Promising RBF solutions are obtained, supporting the numerical methodology. Therefore, the success of the studied model is proven.

Keywords. Radial Basis Function; Mindlin Plate; Single Layer Laminate; Bending Stiffness; Transverse displacement; Shape Parameter.

#171 A Fracture Mechanics Study of a Compact Tension Specimen: Digital Image Correlation, Finite Element and Meshless Methods

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Abstract

This study mainly aims to determine the stress intensity factor range (SIF) for a compact tension (CT) specimen under uniaxial tensile fatigue loading state. A 2D full-field optical technique, Digital Image Correlation (DIC), is used to acquire the experimental solution. Therefore, the deformation contour is measured for several crack growth lengths. In addition, SIF is experimentally characterized together with a numerical overdetermined algorithm for different crack lengths. Besides, the strain variation with respect to the notch tip is captured. The innovation of this study is the combination of an experimental DIC procedure with a numerical overdetermined algorithm. Moreover, to assess the performance of the proposed fracture model, the problem is resolved using advanced discretization techniques, such as the Finite Element Method (FEM) and the Meshless Radial Point Interpolation Method (RPIM). Thus, the cracked CT specimen is elasto-statically modeled using above-mentioned numerical approaches. Hence, the FEM model is analyzed with ABAQUS ©, allowing to compute the mode I SIF results for different crack lengths in addition to strain contours. Likewise, the foregoing procedure is repeated for the RPIM analysis and encouraging numerical results are achieved. The SIF is determined with a maximum energy release rate criterion in front of the crack tip in FEM study, while in RPIM study, it is calculated within the same overdetermined algorithm used in the DIC study. Overall, the experimental and numerical SIF results are compared with the reported solution (ASTM E647) exhibiting a reasonable agreement.

Keywords. Compact Tension Specimen; SIF range; FEM; RPIM; Fracture Mechanics.

#172 A GTN Failure Analysis of an AA6061-T6 Bi-Failure Specimen

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Abstract

In the framework of non-linear fracture mechanics, this study concentrates on the failure prediction of a bi-failure specimen made of Aluminum alloy AA6061-T6 under tensile loading state. Thus, it firstly aims to experimentally evaluate the specimen force/displacement response over a uniaxial tensile test. The mechanical behavior of the material in addition to the modified geometrical properties of the test specimen are fully described. To obtain the experimental data, an advanced optical technique, Digital Image Correlation (DIC), is used to evaluate the internal variables such as displacement in the presence of the failure phenomenon.

To acquire the numerical assessment, the problem is modeled within the Finite Element (FE) formulation in ABAQUS© assuming a defined ductile damage criterion, Gurson–Tvergaard–Needleman (GTN), to attain the intended results. Successful numerical results obtained from FE were validated with experimental DIC data. Here, the failure evolution was perceived by DIC observations, allowing to explain the failure modes. Considering all acquired results, it can be concluded that the presented methodology is capable to predict the material damage and failure process.

Keywords. Stress Triaxiality; Finite Element Method; Digital Image Correlation; Bi-failure; GTN Damage Criterion.

#173 An Elasto-plastic analysis of a DP600 Bi-Failure Specimen: Digital Image Correlation, Finite Element and Meshless Methods

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Abstract

An elasto-plastic study of a bi-failure specimen made of DP600 steel under tensile loading state is proposed in this work. As an experimental study, Digital Image Correlation (DIC) technique is used to measure the reaction force response as a function of the acquired displacement field. In addition, the strain and the stress variation on the specimen surface is also captured. The geometrical and material characteristics are in agreement with the experimental specimen. To access the performance of the numerical schemes, the elasto-plastic model is therefore resolved within two advanced discretization formulations, Finite Element Method (FEM) and Radial Point Interpolation Meshless Method (RPIM), to obtain comparable numerical results.

Numerically, the elasto-plastic plane stress formulation relies on von-Mises yield criteria based on a return mapping algorithm. An iterative process of pseudo-time stepping scheme is applied and incremental displacement steps are enforced. This study uses the Newton-Raphson non-linear solution algorithm to achieve the non-linear solution. The obtained numerical results, such as force/displacement variation and effective plastic strain, are validated with the experimental DIC solution showing that the supporting computational methodology is valid and accurate.

Keywords. Elasto-plastic; Finite Element Method; Digital Image Correlation; RPIM, Bi-failure.

#174 On the Nonlinear Elasto-Plastic Behavior of AA6061-T6: Experimental and Numerical Implementations

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Abstract

In this study, using an elasto-plastic constitutive model, the structural response of an Aluminum alloy AA6061-T6 bi-failure specimen is investigated. The mechanical specifications and material model are fully defined. It is intended to evaluate the force variation versus the displacement field during a tensile loading test. Digital Image Correlation (DIC) approach is used to acquire the experimental data. Afterwards, a 2D model is analyzed through Finite Element (FE) formulation considering an isotropic elasto-plastic regime and the obtained results are compared to DIC outcome. A good agreement between numerical and experimental results was found.

Additionally, the problem is numerically solved using the Radial Point Interpolation Meshless method (RPIM) formulation assuming an elasto-plastic behavior for the material. An elasto-plastic return-mapping routine is defined based on von-Mises yield criteria to evaluate the stress tensor in a pseudo-time stepping scheme, which imposes displacements. Taking into account the non-linear system of equations, a non-linear Newton-Raphson algorithm is used to obtain the converged solution. The RPIM results have a reasonable agreement compared to the DIC solution. The obtained results show that the proposed elasto-plastic RPIM procedure is feasible and robust.

Keywords. Non-linear Elasto-plastic; Finite Element Method; Digital Image Correlation; RPIM, Bi-failure.

#175 A probabilistic approach of a non-linear accumulation fatigue model for stress- and strain-life prediction at variable amplitude loading

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Abstract A probabilistic approach to non-linear damage accumulation for variable amplitude fatigue is developed in this work. A damage model proposed by Huffman & Beckman [1] is used, in which non-linear damage is modeled by calculating the damage of each cycle based on the state of damage when that cycle occurs, using the assumption that damage accumulation behaves like crack growth. The effect is that for any particular reversal to a tensile stress in a variable amplitude stress history, that stress reversal will cause more damage later in a history than it will at the beginning of the history. The probabilistic analysis used in the non-linear damage accumulation fatigue model is based on probabilistic S-N and/or ε-N fields for constant amplitude fatigue data proposed by Castillo and Fernández-Canteli [2]. The non-linear damage model proposed by Huffman & Beckman [1] is generalized for stress- and energy-based criteria [3]. The probabilistic non-linear damage accumulation approach proposed in this paper is validated using experimental variable amplitude fatigue data for riveted joints made of puddle iron from the Fão Bridge under stress-controlled conditions [4,5] and for smooth specimens of P355NL1 pressure vessel steel under strain-controlled conditions [6].

Keywords Fatigue, Non-linear damage accumulation, variable amplitude, probabilistic analysis

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#176 Evaluation of Strength and Fracture Toughness of Ferritic High Strength Steels Under Hydrogen Environments

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Abstract: The achievement of a low carbon society using clean energy is becoming a pressing need due to global environmental concerns and aggravating energy problems. In this context Fuel Cell systems are a potential next-generation energy system. Research and development are thus being conducted to ensure the safety and economic viability of hydrogen stations and Fuel Cell Vehicles, where storage cylinders are submitted to high hydrogen pressures. Nominal working pressure of 70 MPa are nowadays considered.

In this context, the susceptibility of high strength ferritic steels to hydrogen-assistant fracture in hydrogen gas is usually evaluated by mechanical testing in high-pressure hydrogen gas (applying stress concurrent with hydrogen gas exposure) or testing in air after pre-charging the specimens with hydrogen (applying stress following hydrogen exposure). We have used this second methodology, conventionally known as internal hydrogen. Samples were pre-charged in an autoclave under 195 bar of pure hydrogen at 450ºC for 21 hours.

Different chromium-molybdenum steels submitted to diverse quenching and tempering heat treatments were employed. Different samples were also used: small cylindrical samples to measure hydrogen contents and the kinetics of hydrogen egression at room temperature, tensile specimens, notched tensile specimens with an acute notch, and also compact fracture toughness specimens. Fractographic examination in SEM was finally performed in order to know the way the presence of hydrogen modify fracture micromechanisms.

The presence of hydrogen barely affects the conventional tensile properties of the steels but it clearly modifies their notched tensile strength and fracture toughness due to the strong effect that stress triaxiallity (dependent also on the steel yield strength) has on the accumulation of hydrogen on the notch/crack front region, being the displacement rate used in the test another important variable to be controlled, due to its influence on hydrogen diffusion to the embrittled process zone. Moreover, the modification of fracture micromechanisms was finally determined, being ductile (initiation, growth and coalescence of microvoids) in the absence of hydrogen and brittle and intergranular under the more embrittled material/conditions.

The influence of the steel composition and yield strength (tempering temperature) was finally assessed, in order to select the most appropriate steel grade to be used for the manufacture of pressure vessels guaranteeing a safe and long service under high hydrogen pressures.

#177 Extending the fatigue Weibull probabilistic model to the LCF region by using an energetic parameter based on the strain gradient

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Abstract In this work the energetic parameter $\Delta GP^* = \sigma_{max} (d\varepsilon/d\sigma)_{max} - \sigma_{min} (d\varepsilon/d\sigma)_{min}$ is proposed as a plausible alternative to the conventional stress range $\Delta\sigma = \sigma_{max} - \sigma_{min}$, to be included as a reference parameter in the probabilistic fatigue model of Castillo-Canteli aiming at overcoming the limitations evidenced by the basic version of the aforementioned model. In particular, the transgression of the ultimate stress is now avoided the same as the ambiguous interpretation of the minimum number of cycles needed to cause the specimen failure (referred as B parameter in the model), which adopts now an unequivocal meaning as a lower limit of cycles in the low cycle fatigue region. The strain gradients are calculated from the cyclic stress-strain diagram of the material, which is defined by an analytical expression. With this proposal, damage progress is thought to be represented in a more adequate way in an attempt of extending the applicability of the probabilistic model to the LCF domain. Optionally, the conventional $\Delta\sigma - N$ field can be recovered from that referred to $\Delta GP^* - N$, the former adopting the typical sigmoidal shape expected for the experimental S-N field extended to the LCF region. The application of the new energetic parameter to the assessment of experimental results allows a discussion about its suitability to practical design. In any case, the fiction of an ideal fitting of results is emphasized and its relative transcendence is clarified on its actual terms from the perspective of transferability.

#178 A probabilistic non-linear Miner rule

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Abstract. Despite the limitations of the Miner rule, its application is extensively recommended and applied by many standards for practical design. Nevertheless, some of those shortcomings should be interpreted adequately, such as the seemingly linear damage represented by the Miner rule, by means of a so-called non-linear model. One possible cause for the limited application of the Miner number under varying, particularly random, loading can be attributed to the lack of probabilistic considerations and to the impossibility of the traditional Miner approach to reproduce the crack growth process being experienced along the loading history. This can be, at least partly, assigned to the immovable position of the S-N field during the damage process. In this work, a twofold empirical solution is proposed in order to make possible the consideration of non-linear damage: the first one, by modifying the representation of the damage progress (wrongly understood as "linear damage"), the second one, allowing the "basic S-N line" to be shifted properly according to the crack growth process, i.e. with the damage progress. Such implements on a probabilistic fatigue model allow the conventional Miner model to be enhanced. An application to fully different examples illustrates the usefulness of the novel approach.

#179 New Method of Numerical Homogenization of Functionally Gradient Materials

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Abstract Functionally Graded Material (FGM) are the materials characterized by the variation in composition and structure gradually over volume, resulting in corresponding changes in the properties of the material. Such materials can be designed for specific function and applications. Various approaches based on the bulk (particulate processing), preform processing, layer processing and melt processing are used to fabricate the functionally graded materials. There are many ways on modeling such structures, but the main challenge is the structure homogenization .

In the paper the method of numerical homogenization for FGM was proposed It was based on the method shown in Vemaganti K., Deshmukh P.: *An adaptive global–local approach to modeling functionally graded materials*, Computer Methods in Applied Mechanics and Engineering Volume 195, Issues 33-36, 1 July 2006, Pages 4230-4243, in which the gradient heterogeneous microstructure is divided into homogenous slices (Fig 1). In the presented study the model was built with the use of 2D elements, with two linear material models of Young modulus E=45 MPa and 748 MPa distributed in sample volume in accordance to linear and normal distributions (Fig. 1). Firstly the RVE was calculated. Then the numerical homogenization was carried out with the division of the heterogeneous sample into 4, 5 and 8 slices. The substitute material characteristics were calculated and implemented into sliced model. The numerical compression tests of the sliced and heterogeneous models and were compared . The conclusion was that the more slices we apply the more exact results we will get. This selection should be based on the accuracy we want to get and on the computational capacity we have. Also in this kind of modeling we cannot asses the stress distribution in microstructure.

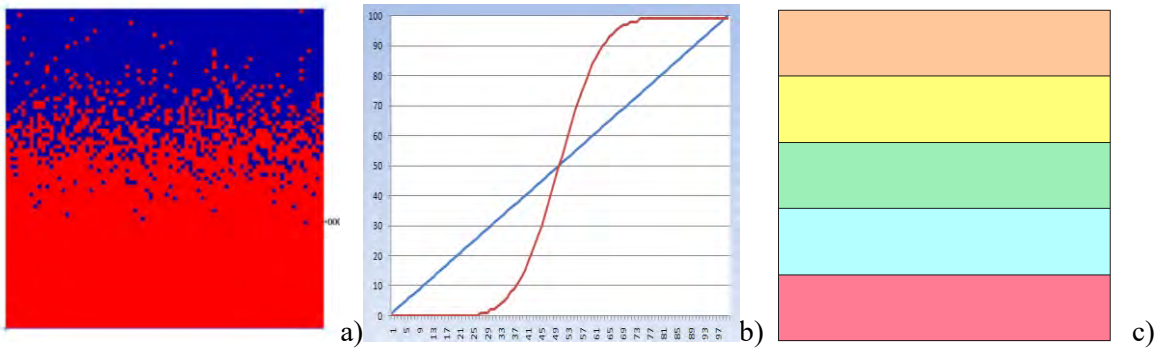

Figure 1 *– The sample of FGM (a) microstructure model with applied normal distribution marked in red (b) and sliced model*

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#180 Assessing the Irradiation Damage using Dislocation Based Crystal Plasticity Model for BCC Materials

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Abstract Radiation effects lead to significant reduction in ductility during the life of the components used in nuclear reactors. Apart from better thermal properties of Body Centered Cubic (BCC) materials as compared to Face Centered Cubic (FCC) materials they have excellent resistance to helium embrittlement and void swelling under higher dpa levels, making them the promising materials for future nuclear reactors. But presence of sharp change in fracture toughness at lower temperature as compared to FCC materials is a major concern restricting their application in nuclear reactors. In the present paper such strong temperature dependence of strain rate and flow stress in BCC materials is investigated numerically for both non-irradiated and irradiated conditions. The BCC materials subjected to radiation would undergo irradiation embrittlement which rises-up the ductile to brittle transition (DBT) temperature up to or above the room temperature. In view of dislocations mobility being a fundamental property to determine the plastic behavior, a dislocations based material model is proposed which is based on physical approach rather than phenomenological. This material model accounts for both thermally activated and athermal regime dislocation mobilities in BCC materials. The material model is capable of predicting the effect of irradiation induced defects on the mobility of the dislocations which in turn directly affect the behavior of such materials. The relative change in dislocation mobility of non-irradiated case with respect to irradiated case provides a valuable input for nuclear material development to have a better performance under irradiation conditions.

#184 Signal processing methods to improve Signal-to-noise ratio (SNR) in ultrasonic non-destructive testing of wind turbine blade

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Abstract Ultrasonic non-destructive testing (NDT) methods are being used quite effectively nowadays, but the multilayered structure of composite materials results in the serious problem in the detection of defects/flaws. The resulting ultrasonic signal is often noisy and denoising of this signal is necessary in order to extract useful information so that the faults can be detected, located and sized in an accurate manner. During the interaction of guided waves with a composite structure, some possible phenomenon such as scattering of guided waves, reflection, refraction or mode conversion occurs. The pulse–echo and pitch– catch are the two most common approaches for structure health monitoring using guided waves. From various characteristics of the received signal, such as the time of flight, amplitude etc., information about the damage in the inspected structure can be obtained. The key factor is the selection of suitable signal processing technique to process the received signal to get information about defects or de-noising it for further processing.

Currently, there is a high demand for automatic ultrasonic signal processing techniques to not only remove the need for manual flaw detection and assessment but also increase the accuracy, reliability, and repeatability of the non-destructive evaluation. There are various signal processing techniques which can be used in ultrasonic measurements and selection of appropriate method is one of the key factors in the field of ultrasonic testing of composite materials.

There are two key composite materials which are used to manufacture the wind turbine blade: CFRP (carbon fiber reinforced plastics) and Glass Fiber Reinforced Plastics (GFRP). There are several non-destructive testing methods can be used to assess the quality of materials used in the manufacturing process of turbine blades. However, dimension and complexity of wind turbine blades and limitation in applicability and accuracy of some methods make them unsuitable for the on-site inspection of wind turbine blades and among the all available NDT testing methods, ultrasonic testing is extensively used for the inspection of these materials.

However, testing of WTB is still quite complex and challenging because of its composite and thick structure, one side access. Therefore, more innovation and research is required in this field. The accuracy depends on various factors including the type of composite material, the sensitivity of the transducers, environmental noise, false positives due to impacts on the piece etc. and can be increased by appropriate signal processing techniques. In the presented work, the various ultrasonic signal processing methods have been compared. The complexity and challenges to perform the ultrasonic NDT for the inspection of WTB have been reviewed and comparative result based on literature is presented. The possible solutions to overcome the structural noise in the inspection of WTB are also discussed.

#185 Tensile and Fatigue Behavior of AA6022-T4 to IF Steel Resistance Spot Welds

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Abstract

Vehicle light weighting plays an integral role in achieving the mandatory fuel efficiency requirements as established in the Corporate Average Fuel Economy Standards (CAFE), USA. To optimize vehicle structures for both performance and lightweight, materials such as aluminum alloys may be used in combination with steels, especially advanced high strength steels. Although joining dissimilar materials is a challenge, General Motors (GM) has recently succeeded in developing a proprietary resistance spot welding process using a multi-ring, domed (MRD) electrode geometry that is capable of producing welds between aluminum alloys and steel materials with acceptable joint strength.

In the present paper, tensile and fatigue properties will be presented of welds produced between dissimilar materials in lap-shear configuration. The dissimilar resistance spot welds (RSWs) were composed of wrought aluminum AA6022 sheet in T4 condition measuring 1.2 mm in thickness and IF steel measuring 2.0 mm in thickness. For comparison, similar lap-shear RSWs were made and tested of 1.2 mm and 2.0 mm thick AA6022-T4. Average lap-shear strengths of 4400 N and 3200 N were observed for AA6022-T4 to IF steel welds and AA6022-T4 to AA6022-T4 welds, respectively. In load-controlled fatigue testing, small scatter in fatigue life was observed for the AA6022-T4 to IF steel welds tested at maximum fatigue loads below 1500 N. The failure mode was mainly due to crack growth through the thickness direction in the AA6022-T4 sheet around the outer edge of the weld nugget. Although very minor scatter in fatigue life was observed for the AA6022-T4 to AA6022-T4 lap-shear welds, the overall fatigue life was lower compared to AA6022-T4 to IF steel welds. Metallurgical analysis of the AA6022-T4 to AA6022-T4 spot welds showed fatigue cracks initiated from microscopic crack-like features, i.e., the notch slit, that forms at the weld notch root adjacent to the edge of the weld nugget. These microscopic crack like features were not observed in the AA6022-T4 to IF steel welds. Overall, the size of the weld nuggets in AA6022-T4 to IF steel RSWs was much larger compared to the AA6022-T4 to AA6022-T4 ones. A combination of internal porosity and micro-cracks as well as a smaller nugget size contributed to lower tensile strength for AA6022-T4 to AA6022-T4 lap-shear welds. Using the structural stress concept, it was found that the fatigue life of lap-shear AA60222-T4 to AA6022-T4 and AA6022-T4 to IF steel welds falls into a master curve indicating that the nugget size dominates the fatigue life.

#186 Fracture analysis and embrittlement phenomena of machined brass components

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Abstract Fracture analysis and metallographic characterization is performed in selected machinable brass components, for use in hydraulic installations. Evidence of brittle fracture was mainly indicated by the presence of intergranular failure and limited plasticity areas. Multiple cracking was observed at the most highly stressed areas, such as the crests of the threads, the cross section transitions and thinnest wall locations. Fractographic analysis performed using Field Emission SEM, suggested the occurrence of embrittling phenomena, probably attributed to overheating and subsequent Pb-phase grain boundary segregation (Fig. 1). Metallographic cross section investigation rather supported the failure hypothesis, implying that hot shortness is the plausible cause of ductility trough and brittle failure.

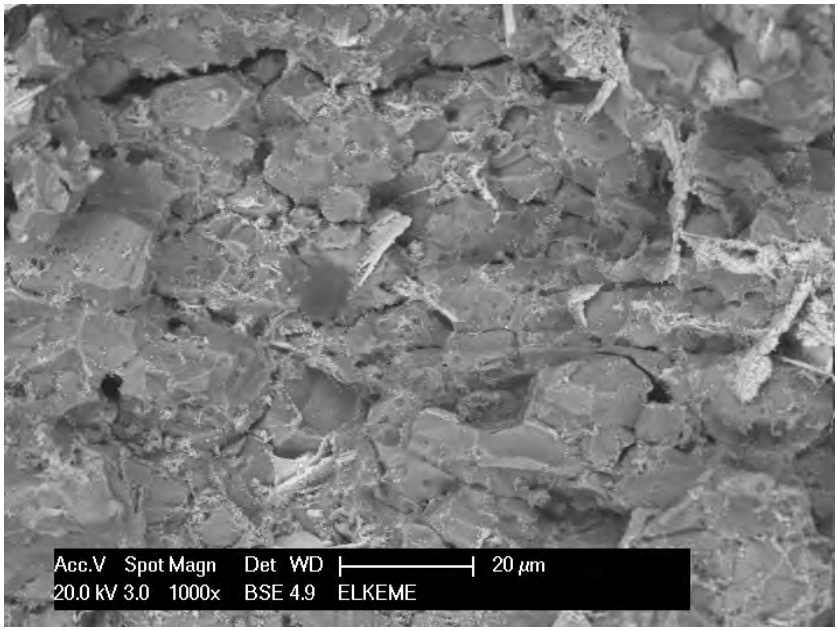

Figure 1 *–SEM micrograph showing the occurrence of brittle intergranular fracture in machined brass component. Light areas represent localized Pb-phase accumulation.*

#187 Laser surface treatments effects: tribological and oxidation at high temperature resistances enhancement of pure Ti and Beta-Titanium alloys

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Abstract

Titanium and its alloys are widely used in aeronautical, marine and chemical industries for their good mechanical properties, high resistance to corrosion and low density. However, the tribological properties of titanium must be improved for many mechanical engineering applications and also its high temperature corrosion resistance especially for aeronautical applications.In last years, laser surface processing has been used in industry and in research laboratory for improving tribological properties of Ti alloys (corrosion, wear and/or fatigue resistance). Indeed large compressive stresses as well surface hardening induced by mechanical process as shock laser seem to play a positive role in the oxidation resistance of materials. This behaviour is observed on pure Ti and Zr.One hand, first purpose was to study the effect of process setup, as laser and surrounding atmosphere on the light element insertion when the targets are treated with a nanosecond pulse duration Nd:YAG laser. This process modifies the surface by formation of specific layers under the substrate. These layers show different properties which are largely influenced by the presence and the repartition of insertion elements in the layers. Then, we specially compare the fretting behavior of commercially pure titanium plates functionalized with titanium oxynitride films obtained by two methods: reactive physical vapour deposition (PVD) and surface laser treatments by using a nanosecond Nd:YAG laser emitting at 1.064 µm. To understand and distinguish the laser light element with oxidation during fretting test, laser treatments were done in a reactive atmosphere composed of different mixtures of oxygen and nitrogen. Moreover, ^{18}O isotope was used for laser treatments with the aim of distinguish the insertion of oxygen due to the laser treatment with respect to oxidation processes associated to Tribological Transformations of Surface (TTS) during the fretting test in air. In the other hand, an experimental campaign led on commercial pure Titanium and Tiβ21S titanium alloy is carried out to understand the difference of SP and LSP treatments and also between pure titanium (alpha based metal) and the Tiβ21S alloy. SP and LSP with the two titanium alloys are compared to untreated samples in terms of oxidation behavior at high temperature in dry air or pure oxygen during 100 h or 3000h. Specimens were evaluated for their oxidation resistance by TGA and subsequently, by several characterizations like hardness, SEM/EDS/EBSD, XPS, nuclear reaction analysis, XRD and Raman spectroscopy and XRD stress determination. A Discussion on the origin of the high temperature oxidation resistance improvement for the both titanium alloys in the case of LSP takes into account different origin, like the nitrogen insertion, the microstructure of the underlayer and also the effect of residual stress. We show that these two laser treatment, reactive hardening by laser insertion (HLI) or laser shock peening (LSP) respectively promotes better tribological behaviour for and also substantially reduces the mass gain and prove the presence of Nitrogen enrichment located at the interface between oxide and α-case layers. Some others effect were consider as NPs formation in the laser plume during treatment.

#188 Silica nanoparticles functionalization and mechanical properties of obtained epoxy nanocomposites

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Abstract Functionalization of silica nanoparticles is needed as to improve the mechanical performance of epoxy nanocomposites in which these are added. Previous experience showed that direct dispersion of commercially available silica nanofillers doesn't improve significantly the mechanical properties of resulting nanocomposites.

Silica nanoparticles from Sigma Aldrich (175-225 nm BET) were functionalized carrying exactly 0.28 mmol of phenylazide per 1g of dry particles. During drying they have macroscopically aggregated and their dispersion has become a challenge. Using mechanical mixing is not an option even at high rpms, so dispersion can be done directly by sonication or using for the beginning a solvent (which should be later removed) as to dissolve the silica conglomerations followed by sonication. Comparisons between using different procedures of dispersion are presented and comments on the obtained mechanical properties established in traction are done.

#189 Impact response of polyurethane and polystyrene sandwich panels

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Abstract Sandwich panels with aluminum faces and polyurethane or polystyrene core were tested in impact on an Instron Ceast 9340 impact tower at speeds from 0.77 to 4 m/s. The faces were made from Al 6082-T6 sheet with a thickness of 1.5 mm and the thickness of the polyurethane panel (Necuron 100 core of density 100 kg/m^3) and of the of the polystyrene panel (commercial extruded polystyrene core of density 40 kg/m^3) were 15 mm, respectively 22 mm. Specimens of 140x140 mm were impacted with a mass of 13 kg and the variations of the impact force and absorbed energy were monitored during the initial impact at a data acquisition frequency of 200 kHz. The important events take place in less than 15 ms.

Particularities of the impact response of the sandwich panels are observed and discussed. The influence of the speed of impact is analyzed for both types of panels. The force variation during impact has a different evolution as influenced by the core morphology. There are noticed differences in the size and shape of the produced damage after impact.

#190 Mixed mode Fracture Behavior of Asphalt Mixtures Containing RAP - 3D Finite Element Analysis

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Abstract Reclaimed asphalt pavement (RAP) is commonly used to improve sustainability of asphalt concrete pavement. The main objective of the present work is to study the effect of RAP content on the mixed mode fracture behavior of asphalt concrete pavement numerically. Extended finite-element model (XFEM) coupled with cohesive zone modeling (CZM) was adopted to simulate the 3D crack growth under mixed mode loading. Semi-circular bending (SCB) specimen was used with two different crack geometries, namely inclined crack at the middle with different inclination angles and vertical crack subjected to asymmetric three point bending (3PB). The effect of specimen thickness on the mixed mode fracture toughness has been studied. The relations between either RAP content or specimen thickness and the mixed mode fracture toughness have been correlated. It is found that, the present 3D finite element model is a good candidate to predict the mixed mode fracture toughness of asphalt concrete pavement containing RAP.

#191 Stress-strain assessment dents in wall of high pressure gas pipeline

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Abstract

The aim of this work is an experimental study of the effect dents on a structural integrity high pressure gas pipeline after decades work with nominal diameter 300 mm. Stress-strain behavior of two dents is evaluated by strain gauges chains oriented in hoop direction. Profile dents is measured by digital sliding scale in circumferential and longitudinal direction in points after 10 mm. Residual deformation are detected after load internal pressure by water to working level. Negative and positive values of residual deformation was occurred due to location strain gauge. Fatigue resistance were performed by 10 000 pressures cycles with load asymmetry R = 0 and maximum internal pressure p_{max} = 7,35 MPa (nominal working level). By influence of internal pressures cycles was occurred increase of values residual deformation. Subsequent pressure burst test assessments limit state of this type defect. Two dwells were realized in 66% and 100% yield stress. Tensile properties and Charpy absorbed energy was taken from small specimens of material pipe. Negative values of strain was observed at strain gauges placed on edge of dents. Positive values of strain was observed at strain gauges placed inside dents. By increasing of internal pressure was occurred the changing shape of dents. Depth dents decrease and revert to the original circular profile tube. The pipe fracture was occurred at the internal pressure of 19 MPa.

#192 Heat resistance research and surface analysis of fireproof textiles with titanium silicide coating

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Abstract The aim of presented work was to study two types of special fireproof textiles covered with titanium silicide coating (Fig.1). In the paper the assessment of the change in heat resistance properties and analysis structure of TiSi coated fireproof textile were carried out.

The aim of the research was to study the influence of TiSi coating on the infrared radiation (thermal) resistance generated in specially designed testing stage. The radiation intensity was registered with the use of thermovision camera. Surface analysis of fireproof textiles covered with TiSi coating using scanning electron microscope was presented in the paper. The research results showed the influence of the applied coating on the heat resistance properties of the textiles.

Presented research is a part of a project the aim of which is to develop a technology for manufacturing the textiles used to produce the protective clothing for emergency services and military, as well as other coated materials for a wide range of applications. The new material should be characterized with increased heat resistance coupled with protection against gas pressure impact caused e.g. by gas installation damage.

Figure 1 - *Example of analyzed textile a) without TiSi coating, b) with TiSi coating*

Acknowledgements

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#194 Uncertainties of the Critical Buckling Pressure of a Tube

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Abstract It is a general design criterion that a tube subjected to an external pressure should not be collapsed during service. For this design method, a critical buckling pressure, P_{cr}, is defined as an external pressure (or difference between the external and internal pressures if an internal pressure is preexisted) at which a tube collapse takes place, which is obtained from the following formula (Griffin, 1965).

$$P_{cr} = \frac{E}{4\left(1-\nu^2\right)}\left(\frac{t}{r}\right)^3, \tag{1}$$

where E: elastic modulus, ν: Poisson's ratio, t: thickness and r: radius of a tube. Eq. (1) has measurement uncertainties of E and ν, and the uncertainties caused by the tolerances of t and r. It is evaluated that the uncertainties of E and ν ($0.25 \le \nu \le 0.37$) are ±1.66% and 8.6%, respectively. For the nominal dimension of $2.55 \le r$ (mm) ≤ 8.25 and $0.25 \le t$ (mm) ≤ 0.89, the uncertainty by the thickness tolerance is the largest, even up to 70% for the worst combination of t and r. Therefore, the safety factor against the buckling failure is primarily determined by the thickness.

It should also be noted that Eq. (1) assumes a perfectly circular cross section of the tube. If an initial ovality (defined as δ/r, δ being the radial deviation), the tube will collapse at a smaller pressure than P_{cr}. Then, the critical buckling pressure of an oval tube, P_y, can be calculated using the following equation (Timoshenko & Gere, 1961).

$$p_y^{\,2} - \left\{\frac{\sigma_{ys}}{m} + (1+6mn)p_{cr}\right\}p_y + \frac{\sigma_{ys}}{m}p_{cr} = 0, \tag{2}$$

where $m = r/t$, $n = \delta/r$ and σ_{ys} is the yield strength of the tube material. It is readily noted that $P_y = \sigma_{ys}/m$ and P_{cr} when $n = 0$ (no ovality). More specifically, if we denote P_{y1} and P_{y2} for the larger and smaller values of P_y, respectively, if $P_{cr} \ge \sigma_{ys}/m$, $P_{y1} = P_{cr}$ and $P_{y2} = \sigma_{ys}/m$; otherwise if $P_{cr} < \sigma_{ys}/m$, $P_{y1} = \sigma_{ys}/m$ and $P_{y2} = P_{cr}$. This implies that P_{y2} gives the critical buckling pressure of an oval tube regardless of t/r because $P_{cr} \le \sigma_{ys}/m$ within the elastic regime.

To investigate the influence of the ovality on the buckling pressure, Type 304 stainless steel tube of $0.02 \le t/r \le 0.2$ is chosen for an example. The mechanical properties are E = 193 GPa, ν = 0.29, σ_{ys} = 215 MPa (www.matweb.com, 2017). For the ovality, n = 0.01, 0.05 and 0.1 are applied.

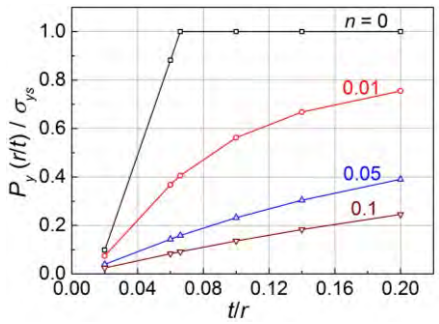

***Figure 1** – Ovality effect on the critical buckling pressure.*

Figure 1 illustrates the result. P_y drops considerably as the ovality increases and t/r decreases. Because the tube should not collapse before σ_{ys} is met, the thickness needs to be increased as the ovality increases. The ovality is found as the most influencial among the uncertainty parameters. Similar technique like Figure 1 gives a guideline of the required minimum thickness to withstand the buckling of an oval tube.

#195 Influence of long-term operation on structure, fatigue durability and impact toughness of 09Mn2Si pipe steel

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Key words: fatigue durability, fracture, structural ageing**,** 09Mn2Si pipe steel, long-term operation, microstructure degradation, embrittlement, impact toughness.

Abstract The degradation of the 09Mn2Si steel of the main gas pipeline "Mastakh-Berge-Yakutsk" after 37 years of operating time was investigated. The main reasons giving rise to failure of pipeline components are harsh climatic conditions, corrosive wear during exploitation, deformation aging caused by prolonged exposure to static loads and structure heterogeneity of the steel. Generalization of the results of our previous studies allows to state that the long operation of the gas pipeline has led to the accumulation of disperse structural and mechanical defects in the material. At the same time, a reasonable assessment of its technical state demands for a comprehensive analysis of steel structure degradation.

It is shown that long-term operation does not give rise to a noticeable redistribution of cementite since during the exploitation the steel experiences mostly low pressure and low temperatures (i.e. heating did not take place). However, its hydrogenation can occur which further leads to decarburization. In doing so the deformation aging is poorly expressed and manifests itself in the precipitation of finely-dispersed carbides in the grain bulk which is responsible for embrittlement under impact bending tests.

The detected degradation does not substantially affect the mechanical properties under static tension and well as data of hardness measurement. The reason for this should be the development of two competing processes: softening as a result of decarburization; hardening as a result of dislocation pinning on the precipitated carbides.

On the other hand, the impact toughness of 09Mn2Si steel after the long operation has been significantly decreased.

The maximum decrease in the impact toughness (by 2.22 times) was observed at testing temperature of T = -70 °C, while the minimum – by 1.48 times at T = 20 °C. The decrease in impact toughness is associated, first of all, with reducing the fracture energy intensity of steel due to dispersion embrittlement which facilitates the reduction in the maximum load at which the main crack is formed.

#196 Novel test prototype for the determination of mode I fracture parameters: application to adhesively bonded electronics

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Abstract Structural adhesives are commonly used in space electronics particularly for bonding ceramic quad flat packages to printed circuit boards (PCB). In such application, adhesive joints are subjected to high loads due to the PCB bending under severe acceleration of the launch. It is thus mandatory to figure out the adhesive mechanical resistance in order to achieve a safe design. The present paper is concerned with the determination of the cohesive properties of an aerospace adhesive in tensile fracture mode. For this purpose, a novel test prototype consisting of a ceramic component adhesively bonded to a PCB plate is designed and tested subsequently in quasi-static loading. In parallel, a finite element (FE) model of the assembly is developed using ABAQUS software. The adhesive joint is modeled by user-defined cohesive elements. The latter are implemented using a FORTRAN user subroutine (UEL) capable of simulating the geometrical and material nonlinearities of the adhesive. A good agreement is obtained between experimental and numerical results after updating. This finding permitted to successfully find out the cohesive parameters of the tested adhesive.

#197 Influence of corrosion morphology in fatigue strength of bolted joints

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Abstract

This note summarizes some recent data from corroded steel bolted connections under fatigue loading. The test specimens, for the fatigue tests, are made of S355 structural steel with preloaded M12 bolts of class 10.9 with a geometry that corresponding to $\Delta\sigma$ = 112 MPa EC3 detail category.

The accelerated corrosion tests have been realized using an electrolyte consisting of an aqueous 3.5% NaCl solution where the specimens were immersed. In particular, in the corrosion test the specimens are immersed for 2 minutes in the electrolyte and then remain 40 minutes in atmosphere at 40 °C.

An atmospheric corrosion in marine-industrial environment is well-represented through corrosion test. Fatigue loading tests of corroded specimens were performed after the corrosion tests and the obtained results were compared with those obtained from not corroded specimens

#198 Approximation of the crack driving force for cracks at notches under static and cyclic loading

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Abstract The most widely spread standards and guidelines for the structural assessment of structures containing cracks, such as EPRI or SINTAP/FITNET, rely on approximation formulas for the evaluation of the crack driving force. The same approach is used in fracture mechanics-based methods for the estimation of the fatigue life of components, but with a substantial difference: While the former apply the elastic-plastic fracture mechanics to allow for ductile tearing and plastic collapse, the latter are in most of the cases simplified approaches, which are based on linear-elastic fracture mechanics. Nevertheless, it is well-known that the small-scale yielding condition is not always applicable even in fatigue, for instance in case of the propagation of mechanically/physically short cracks, for which the extension of the plastic region is in the same order of magnitude as the crack length. A further important application is given by cracks growing at notches.

The work deals with the efficient calculation of the elastic-plastic crack driving force (J-integral for monotonic loading and ΔJ-integral under cyclic loading) of short cracks at notches as essential parameter for the reliable static and fatigue assessment of notched structures. The J- or ΔJ-integral is calculated based on analytical solutions for stress intensity factors, estimated by means of well-known weight function solutions in the case of cracks under power-law stress distributions. A plasticity-correction function is applied to the stress intensity factors to obtain the final expression of the crack driving force.

Analytical solutions have been generated for different cracks at different notches in welded joints and compared to finite element solutions. In the finite element analyses, the material behavior has been described by a Ramberg-Osgood relationship in case of static loading, whereas the Chaboche material model has been employed in the simulations of cyclic loading. Results show that the approximation formulas provide values of J and ΔJ very close to the finite element results even in case of mechanically short cracks under cyclic loading, which allows to use this methodology for a reliable and efficient calculation of the fatigue life of notched components.

#199 Geomechanical characterization of some adobe materials

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Abstract The appreciable influence of the material properties in the physical and numerical modelling of historical buildings suggests identifying proper laboratory procedures for their mechanical characterization. Some relevant conditions should be considered in this process, e.g.: (a) often the material used for the walls (and their foundations) is available in limited quantity; (b) in the field its water content may vary during time (due e.g. to heavy rainfalls); (c) the shear strength could be reduced when the material is subjected to wetting/drying cycles.

In the presentation some aspects are discussed of the geotechnical laboratory tests suitable for the characterization of some materials used in historical heritage.

Apart from the conventional identification and classification procedures, the unconfined compression, the triaxial and the direct shear tests could be considered. The first one involves a simple laboratory procedure. The second test involves a relatively complex laboratory procedure, however provides detailed results on the stress-strain behaviour of the tested material. The third one is less accurate than the second one, but requires a device available almost everywhere in the geotechnical laboratories.

In the present context both 'natural' and re-constituted samples of adobe reinforced with plant fibers were tested. The 'natural' samples were trimmed from small adobe blocks and the blocks were recovered from the collapsed walls in a building of the historical heritage of Aliano (Basilicata, Italy).

The investigation on the re-constituted samples was necessary for verifying the influence of the fiber content. On the basis of the experimental results obtained from uniaxial compression tests, some preliminary conclusions are drawn on the effects of the fiber content on the overall mechanical properties (that is stiffness, peak and residual shear strength).

With reference to the tested materials, the study intends to provide some additional experimental information, with respect to that already available in the literature, for the development of constitutive laws applicable in the numerical analysis.

Considering the observed damages of an ancient structure in a monument site, it is shown that the numerical analysis can be used at obtaining an insight into the causes that induced the severe structural damages. The numerical results lead also to some conclusions on the possible provisions which can be adopted for the stabilization and restoration of the site.

It is concluded that the numerical analysis can be used in comparing the effectiveness of various alternative solutions that could be applicable in the field for the restoration of buildings that characterize monument sites.

#201 A novel flaw alignment approach based on band of maximum strain using full-field deformation analysis

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Abstract: Standardized approaches for engineering critical assessment of defected structures contain procedures to evaluate the effect of interaction between multiple defects. These procedures typically consist of two stages; alignment rules and combination rules. The former allows to categorize non-planar flaws as either aligned or non-aligned. Following, the latter classifies aligned flaws as interacting or non-interacting. Although these criteria are equally applied to different failure modes such as brittle fracture, elastic-plastic fracture and plastic collapse, most of them were initially developed based on linear elastic fracture mechanics for the sake of simplicity and conservativeness. Therefore, the application of these procedures might be questioned when applied to failure modes other than brittle fracture.

This study attempts to develop an alternative methodology to evaluate alignment of non-co-planar side edge notches in tensile loaded specimens in presence of large plastic strains. Hereto, strain patterns are studied based on full-field deformation measurements utilizing Digital Image Correlation (DIC). The results show that, in addition to crack driving force which represents a very local behavior of defects, the global behavior of the specimen in terms of strain patterns can be used to reveal interaction between non-co-planar flaws. The authors propose a novel approach based on bands of maximum strain to distinguish between aligned and non-aligned flaws. It is believed that this can give an illuminating insight to flaw interaction phenomena for future studies.

#204 Effect of grinding process on surface integrity of hard materials.

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Abstract The grinding process requires an important specific energy in comparison with other conventional machining processes. It's well known that the greater part of the consumed energy is converted into heat in the grinding area which could lead to an important increase in temperature. Therefore, an uncontrolled grinding process may cause different kinds of damage such as thermal burnings of the surface layer, cracks, softening. Depending on the material under investigation, these damages can take different forms. In this work, two hard materials are used: an electroliticaly deposited chromium layer on steel (Weiss *et al*., 2016) and a nitrided steel (Lavisse *et al*., 2017). As temperature plays a key role in these grinding processes, it is important to accurately evaluate the temperature in the contact zone and to clarify the role of the lubrication process. For this study, a foil/workpiece thermocouplehas been used to measure temperature in the grinding zone. Microstructural observation including both SEM, EBSD, texture and XRD stress analysis coupled with micro-hardness measurement are performed to described the microstructural state of the surface and sub-surface of the material after grinding. RAMAN spectroscopy has been performed to determine the different oxides formed when burns appears after grinding. Depending on the cutting force and on grinding parameters, several types of burns have been obtained. According to the boiling temperature of the lubricant, the heat affected zone and the mechanical affected zone are clearly related to the temperature in the grinding zone for all materials. Based on these measured temperature profile, an inverse method using the moving heat flux theory enable to obtain the heat flux distribution in the grinding zone and consequently the temperature profiles within the material. These profiles can be used to determine the size of the heat affected zone. The mechanical deformed zone is obtained by direct SEM observation and EBSD analysis of the cross-section of the grinded material.
As a result, it is clearly seen that burning deeply affect the material. Different areas can be clearly distinguished: heat affected zone, mechanical affected zone and metallurgical affected zone depending of the kind of material under investigation. From a mechanical point of view, the residual stresses evolve for the two materials according to a competition between thermal/tensile and mechanical/compressive stresses. The mechanical affected zone does not seem to depend on the material structure. In every case, a finely and highly disturbed layer showing very small grains is observed. The width of this layer depends clearly on the grinding parameter and else, on the achieved temperature in the contact zone. This last one also determines the size of the metallurgical affected zone which can be more particularly damaging for the material. In the case of the chromium coating under hard grinding condition, several cracks are observed in the chromium layer and in the substrate. As a matter of fact, and based on the different measurement and observation, the lack of trace of burn marks on the surface of the chromium layer or of the nitrided steel does not always mean that the substrate is not affected.

Weiss B., Lefebvre A., Sinot O., Marquer M., Tidu A., *Effect of grinding on the surface and sub-surface of electrodeposited chromium and substrate*, *Surface & Coatings Technology*, 272, pp. 165-175 (2015)

Lavisse B., Lefebvre A., Sinot O., Henrion E., Lemarié S., *Grinding heat flux distribution by an inverse heat transfer method with foil/workpiece thermocouple under oil lubricant*, *International Journal of Advanced Manufacturing*
Technology, (2017) *Accepted*

Keywords: Grinding, nitrided steel, foil/workpiece thermocouple

#205 TSA based evaluation of fatigue crack propagation in steel bridge members

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Abstract

Fatigue crack propagation in aging steel bridges has become a serious problem. Nondestructive evaluation of fatigue damage propagation is necessary to ensure safety and to estimate the remaining life of the bridges. Conventionally employed nondestructive testing (NDT) techniques such as visual testing, magnetic particle testing and ultrasonic testing are time- and labor- consuming techniques, further these NDT techniques cannot be used to directly evaluate the remaining strength of the bridges. Thermoelastic stress analysis (TSA) using infrared thermography has been widely used as an effective full-field experimental stress measurement technique. In this study, TSA was applied for on-site measurement of stress distributions around fatigue cracks, and the future crack propagation behavior was estimated by the fracture mechanics approach. Experimental studies were conducted for laboratory specimens which modeled a part of welded structure in steel bridges. The stress intensity factors were calculated from stress distributions measured by TSA technique. Figure 1 shows an obtained relationship between stress intensity factor ranges and crack propagation rates. It is found that the obtained relationship shows a good correspondence with the Paris law. Further TSA technique was applied to evaluate the effectiveness of repair or reinforcement for defective portions. Severity reduction in stress distribution around the fatigue crack after treatment was confirmed for actual steel bridge members by TSA. Crack propagation rate was estimated from the stress intensity factor calculated from on-site stress measurement data. As the result, 55% reduction in crack propagation rate was ascertained indicating the positive effect of the crack repair.

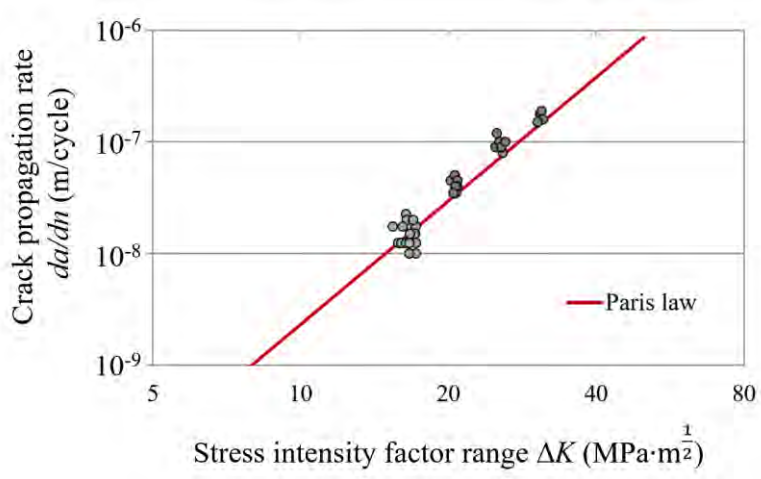

Figure 1 - *Relationship between stress intensity factor range and crack propagation rate obtained by TSA technique.*

#207 Numerical Analyses of Corroded Bolted Connections

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Abstract This note summarizes some recent results carried out from fatigue f.e.m. analyses of corroded steel bolted connections with the aim to investigate the effects of corrosion pits on the fatigue life of the studied joint. The results of numerical analyses, compared with which obtained from experimental tests, show that the corrosion pits reduce the fatigue strength of the joint due to a local stress concentration in correspondence of the pit where occurs the crack propagation under cyclic load. In this work, a simplified numerical strategy for modelling corrosion pits in fatigue f.e. analyses of S355 steel bolted joint is proposed with the aim to assess the local stress concentration caused by pit and drawing the corresponding S-N curve for the corroded joint.

#208 Estimation of the dynamic modal parameters of a small-scaled mockup

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Abstract This paper presents the experimental and numerical research carried out on a reduced-scaled model to obtain and simulate its dynamic modal properties. The experimental mockup consists on a three-story structure in a shear frame configuration. Due to the discrete nature of the structural system, the shear frame can be modeled as a three degree-of-freedom (dof) structure with three lateral displacements representing the vibration of each mass. Thus, three accelerometers located at the reference nodes or masses (i.e., at the expected higher modal amplitude points) were used for the experimental tests. Then, a roving impact hammer test was carried out to identify the dynamic modal properties of the structure (frequencies, modal shapes and damping). The measured input and output values were adquired using a Data Acquisition System (DAQ) in order to compute the corresponding Frequency Response Function (FRF) measurements to characterize its dynamic response. Finally, the experimental results were used to optimize the parameters of a numerical model of the mockup. In this case, the model updating procedure is based on an optimization problem in which a set of parameters representing uncertanties in the modeling process of the mass, stiffness and damping is optimized to minimize the diference between the predicted and measured dynamics of the actual structure.

#209 Optimization of machining parameters to improve the surface quality

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Abstract: The preparation of quality surfaces is very important process in the surface engineering. The surface roughness will influence the quality and effectiveness of the subsequent coatings for protection against corrosion, wear resistance and decorative effects. For this reason, the authors of the present work have focused in manufacturing parameters that influence the surface quality of hardness metallic materials.

In this work, the effects of varying four parameters in the milling process (cutting speed, feed rate, radial penetration and axial penetration) are analyzed individually and the interaction between some of them, in the roughness variation in hardened Steel (steel 1.2738). For this analysis used the Taguchi optimization method.

Using the method was built a L16 orthogonal matrix and for each parameter were defined two different levels and made sixteen trials. In Fig. 1 is possible to observe the obtained results.

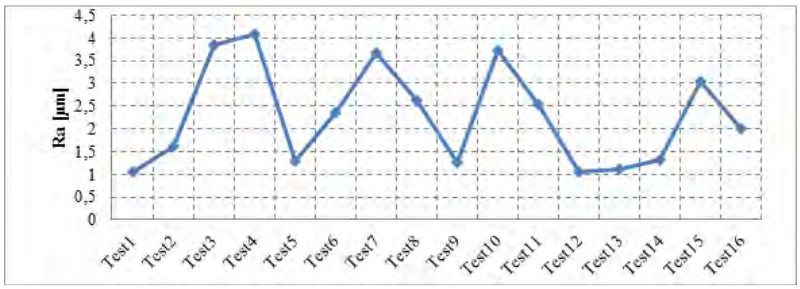

Fig. 1. Average roughness value for each test

After each test, there was the surface roughness measurement of the workpiece. Based on the results obtained from surface roughness measurements it is made a statistical treatment of data by analysis of variance (ANOVA) to determine the influence of each parameter in surface roughness. It is noted that the minimum roughness was measured 1.05µm.

This study also determined the contribution of each of the machining parameters and their interaction for surface quality. Was verified that the most important factors are the radial cutting depth and the interaction between the radial and axial depth of cut to minimize surface roughness. These contributions have about 30% and 24%, respectively.

#210 Structural damage detection of a cantilever beam under varying temperature using a collection of time series measurements

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Abstract. Condition monitoring of structures in service is very important as it provides information about the risk of damage development. One of the essential constituents of structural condition monitoring is the damage detection methodology. In the context of condition monitoring of in service structures a damage detection methodology analyses data obtained from the structure while it is in operation. Usually this means that the data could be affected by operational and environmental conditions in a way that could mask the effects of a possible damage on the data. This, depending on the damage detection methodology, could lead to either false alarms or miss existing damages.

A damage detection methodology that is based on the Spatio-temporal continuous wavelet transform (SPT-CWT) analysis of a sequence of experimental time responses of a cantilever beam is proposed. The cantilever is excite by white and pink noise and is subjected to changing environmental conditions. Its response is measured by a high speed camera and from the series of the response images the edges are extracted. This yields a collection of time series that is analyzed by the SPT-CWT to identify damage and the effects of the varying temperature and excitations.

This methodology identifies the effect of the damage and separates it from that due to temperature and excitation on data obtained from measurements off a cantilever beam. This methodology does not require information about the a-priory state of the structure.

#211 Effects of laser power on delamination initiation behaviour of CrAlN coating on steel substrate laser- quenched after coating process under rolling contact fatigue

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Abstract In order to investigate the effects of new surface modification method "Laser quenching after coating" on the rolling contact fatigue strength of ceramic coated steel, CrAlN coated specimens were processed by this method under various laser power conditions, and the thrust type rolling contact fatigue tests were carried out for these specimens. Figure 1 shows the relationship between delamination initiation life of CrAlN coating and laser power. The delamination initiation life of CrAlN coating increased with the laser power, however the excessive laser power decreased the delamination initiation life.

In order to investigate the reason for the variation of delamination initiation life, the adhesive strength and the hardness of laser irradiated CrAlN coating were investigated. Figure 2 shows the measurement results of the adhesive strength and the hardness of CrAlN coating. The adhesive strength of CrAlN coating showed similar variation with the delamination initiation life for the increase of the laser power. The film hardness was almost constant for the increase of the laser power, however the excessive laser power also decreased the film hardness. From these results, it was considered that the increase of the delamination initiation life of CrAlN coated specimen was caused by the increase of the adhesive strength, and the decrease of the delamination initiation life at high laser power was affected by the decrease of the adhesive strength and the film hardness.

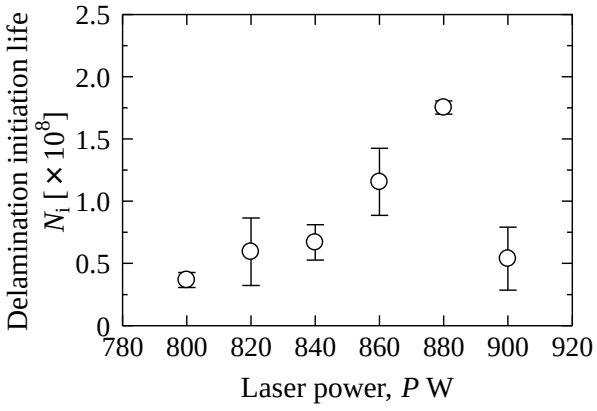

Figure 1 - *Relationship between delamination initiation life of CrAlN coating and laser power*

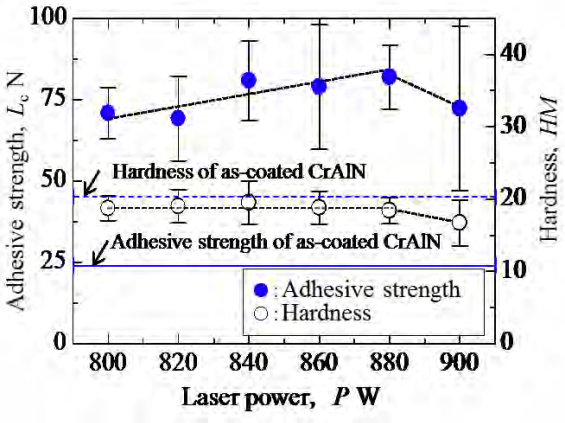

Figure 2 - *Adhesive strength and hardness of laser irradiated CrAlN coating*

#212 Hyperelastic material models of polymers of automotive LED lamp construction used for robust fatigue analysis

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Abstract: The object of this paper is to determine the statistics of parameters of hyperelastic model specific to polymer materials used in automotive lamps. The modern automotive LED lamp housings and lenses are constructed of polymers providing a substantial weight saving and design flexibility. The material switch is attributed to the stringent emission legislations as well as functional requirements, allowing the realisation of highly sophisticated and complex lighting designs. Traditionally, the lamp assemblies are designed and developed based on accumulated knowledge. The historical information becomes vital as the lamp assemblies are subjected to very harsh loading, which is of wider frequency spectrum. The complexity of modern lamp design – the shape and size, the use of alternative material and manufacturing involved, however, have made products susceptible to fatigue failure from vibrational loading. There is a drive towards virtual prototyping to address this aspect by using finite element methods.

The key to robust fatigue analysis of lamp assemblies is the availability of reliable input parameters, such as material models and variability in the behavior of manufactured constructions. Typically, each lamp has parts made of several different materials. In this study, the elastic behavior of two such materials, an amorphous and a semi-crystalline material, is modelled using appropriate hyperelastic models. The stress-strain curves of the materials were measured under uniaxial tension using a non-contact video gauge. Five samples each were tested to measure the effect of manufacturing variability. The model parameter statistics are determined which can then be used to assess the influence on the fatigue behaviour and in the development of probabilistic approaches.

Both materials show nonlinear elastic behavior – this has a huge impact on fatigue failure studies as the strain levels experienced by lamps under vibration loading are higher. The degree of non-linearity in elastic behavior, however, varies. Accordingly, the order of hyperelastic model being suitable varies; the most appropriate model for each material is suggested. The manufacturing variability also differs from material to material; the semi-crystalline polymer shows large inter-sample variation. Probability distribution functions are constructed based on the limited data enabling sampling for probabilistic modelling.

The study shows that linear elastic models are not appropriate in analysing the fatigue behaviour of modern automotive lamp construction. The detailed hyperelastic models of varying order are required. The effect of manufacturing variations needs consideration so that reliable virtual prototypes can be developed.

#214 Mycostone: A comprehensive approach on the study of limestone biodeterioration

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Abstract Recently, the 'University of Coimbra – Alta and Sofia' was granted the World Heritage status and included in the classified area are important limestone monuments which currently exhibit important signs of deterioration. The physical and chemical characteristics of this particular stone deem it more prone to natural weathering, climatic interference and biotic agents such as algae, fungi and bacteria. Usually part of a complex community, these microbial populations can thrive on both the surface and interior of porous limestone and their combined actions lead to chemical shifts in the composition of stone, disaggregation, aesthetic damage, loss of information and, ultimately, pose a threat to the preservation of important historic and artistic landmarks for future generations.

Mycostone is a multidisciplinary project intended to better understand the relationship between these biological communities and the limestone on which they thrive. The Cloisters from the Old Cathedral (Sé Velha) - built between the 12th and the 13th century – were the first to fall under the project's scope. The multi-analytical approach used in this location aims to characterize the decay products and the mineral and aesthetic alterations promoted by the exuberant biological communities encountered using microscopy techniques such as SEM, OM, XRD, FTIR and RAMAN and morphological and state-of-the-art DNA analysis. Environmental air samples are also being performed in order to assess their contribution to the biological diversity encountered on stone.

The preliminary results obtained so far are valuable contributions to the understanding of stone biodeterioration, how it unfolds, and to have a better knowledge of the relationships between specific biodeteriorating organisms, substrata types and deterioration phenomena. A better response, both in terms of prevention and mitigation, is expected to be one of the most relevant outputs of this project.

#215 Dynamic Tests for Assessment of Pedestrian Comfort and Fatigue Life Estimations for Design of a Stayed Highway Bridge

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Abstract. Assessment of the performance of a road bridge for comfort and fatigue of stays at design stage is often carried out following simplified rules defined by design codes of practice. The purpose of this paper is to assess the effectiveness of one such simplified procedure by means of actual dynamic load tests carried out on an unconventional cable-stayed bridge with precast pre-stressed deck and solid section 47 mm diameter steel bars acting as tension members in lieu of specific traditional strand cable systems (Figure 1). The rule given by the Spanish Design Code (IAP -11, "Instrucción sobre las acciones a considerar en el proyecto de puentes de Carretera", 2011) is taken as the basic design requirement to be assessed by a series of time records of the vertical acceleration caused by passage of the control vehicle. The tests consisted on recording vertical component of accelerations at the mid-span section where the stays converge just outside of the pedestrian sidewalk. The control or reference vehicle used for the tests conforms to the requirements described in the Spanish IAP-11 Code: total weigh 40 metric tons, with given axle and wheel configurations. The accelerations caused by a series of controlled passages at 20, 40, 60 and 80 km/h along the axis of the bridge were recorded and analyzed. Transient vibration records for small impact loads were also used in order to obtain an experimental evaluation of the lower natural frequencies and corresponding damping values. The focus of paper is to establish a direct comparison between the code-prescribed analysis of the structure under the reference vehicle, to both evaluate pedestrian comfort and stress oscillations, and assess fatigue life of the stays according to IAP-11. Computed accelerations at the mid-span section are found to be approximately one half of the measured values, fact that is attributed to the various assumptions such as ignoring the inertial mass and mechanical characteristics of the vehicle that does not allow for vehicle-structure interaction. The foregoing results point to the need to review the mechanical characteristics of the reference vehicle and analysis methods to be used in comfort and fatigue life predictions for this type of highway bridges.

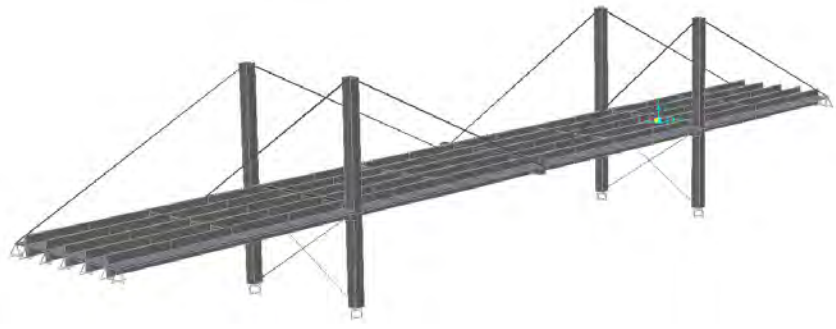

Figure 1 - *Layout of an existing bridge similar to the new bridge under design*

#216 Combined influence of compliance and curvature of substrate on coating delamination

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Abstract The work is aimed at mathematical modeling of coating delamination. Due to difference in geometric parameters of the delaminations it is convenient to use beam, plate or shell theories. The special attention should be given to specifying the appropriate boundary conditions. At first approximation conditions of rigid clamping are used. More accurate results may be obtained using conditions of elastic clamping, where angle of rotation and longitudinal displacement at the clamping point are proportional to the acting moment and longitudinal force (by means of 2x2 matrix of compliance coefficients) [1-4]. However for curvilinear delaminations normal displacements of the points of clamping and transverse forces becomes essential. Therefore the boundary conditions of generalized elastic clamping seems to be more accurate. According to condition of this type the rotation angle and to components of displacement vector at the clamping point are related to the acting moment and two components of the total force by means of 3x3 matrix of compliance coefficients [5].

The scope of tasks to be solved while addressing the problem of coatings delamination includes: (i) obtaining solutions for coefficients of clamping compliance using analytical semi-analytical and numerical methods; (ii) solving problems related to coating delamination in the frame of beam, plate, shell models with the boundary condition of the type of elastic clamping, with parameters determined at the previous step.

In particular, reducing the problem of strip attached to a semi-plane or another strip of different material to the matrix Riemann problem and solving it with the Wiener-Hopf method, the asymptotic expression for coefficients of the extended (3x3) matrix of clamping compliance have been obtained for the number of particular configurations.

The problem of coating delamination from the cylindrical compliant substrate has been addressed. Two types of prolonged blisters have been considered – along axial and circumferential directions: for each type of blisters the energy release rates have been calculated for their propagation in both axial and circumferential direction. For both cases tendencies for blister elongation has been observed. The general problems of determining the direction of blister propagation and conditions of stability loosing of blister configurations of particular types are also discussed. The obtained results may also be useful for other applications such as interpretations of blister tests.

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#217 Reinforcement Measures to Reduce the Human Induced Vibrations on Stair Steps – A Case Study

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Abstract: In recent years, mainly for aesthetic reasons, it has become increasingly popular to design educational buildings, hotels, hospitals and other public areas with slender and lightweight monumental staircases. This often results in flexible staircases which are highly susceptible to vibrations induced by man and fails to satisfy the serviceability limit states. Most of the information found in the literature on flexible staircases that are dynamically responsive is mainly associated only with global vibrations, i.e. vibrations in which staircases moves as a whole. However, if the connections between the steps of the staircase and the staircase itself have low stiffness, this may cause the dynamic behaviour of these two structural elements to be independent of each other, that is, the vibrations in the steps may be different from those verified on the staircase that it supports them. When the response of the steps is independent of the response of the staircase it's referred as local vibrations. In many cases, especially when the length of the steps is long, it is observed that local vibrations can reach excessive levels of response.

This paper presents a case study of a steel stair whose local vibrations were quite significant. With the aim to reduce them several reinforcement measures are proposed. In order to achieve this, initially the vibrations on the steps of the steel stair analysed were measured experimentally. Then a realistic numerical model of one of the stair steps was elaborated using software SAP2000. The model was calibrated so that the numerically obtained vibrations were very close to those measured experimentally. After the numerical model was calibrated, it was modified with several reinforcement measures and the vibrations were recalculated for each of the proposed solutions. In total, eight reinforcement measures are proposed, all of them are made with the objective to be possible to apply in practice. Finally, the vibrations obtained numerically through each reinforcement measure were compared with the level verified experimentally and then with the limits proposed by the design guide SCIP354.

The experimental accelerations on the steps were generally extremely high, reaching in many cases values higher than twice the gravity acceleration (≈9,81 m/s^2). In terms of conclusion, it should be noted that it was not possible with the eight reinforcement measures applied to achieve accelerations lower than the limits proposed by the design guide SCIP354. However, taking into account the fact that the experimental accelerations are approximately double the gravity acceleration (≈9,81 m/s^2), it can be affirmed that with almost all proposed solutions it was possible significantly reduce these accelerations.

#218 Application of the Effective Impulse Approach to Stairs

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Abstract: Vibration serviceability is becoming an increasingly important research topic thanks to pedestrian structures such as footbridges and monumental stairs that have failed, in full public view, to perform adequately under human dynamic loading. Nowadays the majority of the structures subject to dynamic forces induced by pedestrians are designed with fundamental frequencies higher than 10Hz, to avoid the occurrence of resonant effects. However, the use of lightweight materials in the construction of structures with high stiffness, causing high fundamental frequencies to be obtained, may not be the most appropriate. Reducing the mass of the materials reduces the inertia, so an impulsive response can also lead to considerable vibration problems, as it can be seen in the steel staircase analysed and presented in this paper.

Depending on the type of dynamic response, structures can be divided into two categories, low and high frequency structures. Low frequency structures (LFS), as the name implies, are those whose fundamental frequency is low, while high frequency structures (HFS) are those whose fundamental frequency is high. The main difference between these two kinds of structures is that LFS respond harmonically with a resonant response and HFS respond impulsively with a transient response.

Based on Kerr's walking force data, ARUP company developed a simplified method for predicting vibrations in floors with high fundamental frequencies, based on an 'effective impulse'. Although they claim the effective impulse approach is superior to other methods because it is based on fundamental theory, the same was only developed to be applied in floors and is questionable his further use in other structures.

The objective of this paper is to assess if the effective impulse approach, mentioned before, can properly predict the vibrations in this type of structures. In order to do that the vibrations on a steel staircase, which had a well-known level of liveness, were measured experimentally and then compared with the vibrations calculated using the effective impulsive approach.

Although the effective impulse approach was designed to be applied on floors and is not defined how can be applied to stairs, in this study it was been possible to achieve satisfactory results on the stair descends with different footfall rates, since the vibrations measured experimentally were approximated with those predicted. Regardless of being possible to obtain satisfactory results in the stair descends it is suggested that an impulsive effective approach should be conceived to be directly applied to stairs, to take in account the distinct dynamic forces and footfall rate employed when descending and ascending the stairs from that verified when walking across horizontal surfaces (floors).

#219 Transferability of Laboratory Results to Probabilistic Failure Design of Glass Plates

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Abstract In this paper, the generalized local model (GLM) is applied, as a procedure to derive the primary failure cumulative distribution function (PFCDF) of annealed glass related to an adequate reference parameter, thus allowing failure prediction of structural glass plates to be achieved. The main goal of this work consists in demonstrating, first, the uniqueness in the characterization, i.e. of the PFCDF, of glass irrespective of the test and specimen size and geometry used, second, the possibility of joint assessment of results for different tests and, third, the transferability of the laboratory results performed on simple specimens to the practical design of glass components. To achieve this goal, annealed glass specimens of distinct shape and size were tested in an extensive experimental programme comprising four-point bending and coaxial double ring tests. The data assessment using this model gives a satisfactory explanation to the lack of agreement in the characterization, given as failure strength results, attempted up to now on such a material from various experimental programmes. The GLM allows the suitability of the reference parameter taken as a reference for the failure prediction to be checked. Finally, it should be noted that the generalized parameter distribution is determined by finite element computation under general loading conditions. As a consequence, the generality of the method is ensured for components design rather than being restricted to the characterization of laboratory specimens.

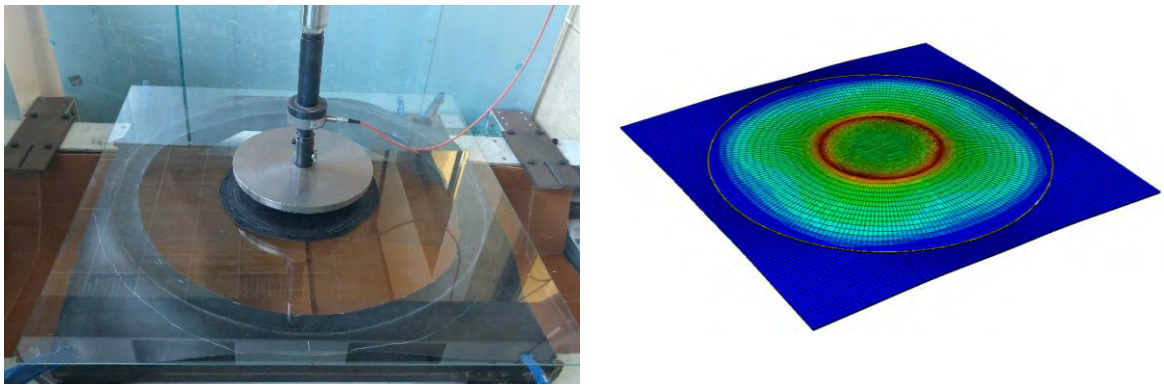

Figure 1 – *Coaxial double ring test set-up and FEM stress results for large glass plates.*

#220 Mixed-mode fracture characteristics of metal-to-metal adhesively bonded joints: Experimental behavior and numerical simulation

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Abstract The fracture behavior of adhesively bonded joints subjected to mixed-mode (i.e. Mode-I and Mode-II) loading conditions is of particular importance in a number of industrial applications such as aerospace, marine, nuclear, automotive and civil constructions. This research therefore aims to characterise the failure behaviour of metal-to-metal (i.e. both aluminium adherends) adhesive joints using the mixed mode bending test (MMB), adapted from ASTM D-6671, along with acoustic emission (AE) sensor based monitoring technique. Thirty adhesively bonded specimens were prepared using two types of adhesive bond materials (acrylic based tough bond and cyanoacrylate based brittle bond) with two different bonded area 65% and 100%. In order to understand the effect of mixed-mode loading conditions on the failure behavior, three different mixity ratios were achieved through the design of the MMB test fixture and tested for each bonded joint. Prior to mechanical testing, the adhesive bonded specimens were examined using AE to obtain in-depth understanding of signal transmission and signal structure.

The AE results shows that the time domain signals were spread over the loading phase with distinct frequency domain features for different mixity ratios. Also, the fracture behavior of the bonded joints was simulated using cohesive zone modelling (CZM) method using ANSYS Workbench software to understand the stress distribution in specimen when considering a combination of various loading conditions. In addition, an analytical method (e.g. corrected beam theory or CBT) was used to determine strain energy release rates of each specimen. Also, various microscopic observations were conducted on the fracture surface to investigate the failure modes of bonded joints to analyse the adhesive quality effect on interfacial fracture toughness. The results show that both the brittle and ductile specimens exhibited higher energy release rates when Mode-II proportion of loading was increased during the crack initiation phase. The ductile adhesive however demonstrated greater overall fracture toughness than brittle adhesive for all three mixed-mode conditions. The proposed measurement can be useful to assess the overall structural health of bonded system (e.g. structural panel, pipe-in-pipe) and identify defects that can significantly reduce the strength and reliability of material and consequently increase the risk of component failure.

#222 Dynamic Assessment of the São João Bridge Structural Integrity

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Abstract São João Bridge is a prestressed concrete bridge, with a total length of 1028 m, including a main span of 250 metres, two 125 m side spans and approaching viaducts from both sides of the riverbanks. Designed by Edgar Cardoso, this railway bridge crossing the River Douro, in Oporto, Portugal, is open to traffic since 1991.

This bridge was instrumented during the construction and its structural behaviour has been experimentally followed since then. However, the observation of the bridge was based only on periodical measurements. Ten years ago, this system was updated in order to introduce automatic data acquisition with remote access.

In 2014, a vibration-based continuous monitoring system, including 6 uniaxial accelerometers, was installed on the bridge. In order to achieve the identification of modal parameters of the structure on real-time, an integrated procedure was developed to automatically carry out the data processing and to extract the modal parameters, using the Stochastic Subspace Identification technique (SSI) and cluster analysis.

This paper presents the evolution of its structural health monitoring system, as well the procedure developed for the dynamic assessment of the São João Bridge. Some experimental results are presented and compared with the values predicted by a finite element model. The influence of both environmental conditions and operational factors is discussed.

***Figure 1** – São João Bridge*

#223 The impact of the corrosion on the structural behavior of the truss railway bridge

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Abstract The paper describes the results of the assessment of the old truss railway bridge, build in 1990. The bridge with one railway track crosses the Hracholusky dam in the Czech Republic with three spans of 57 m. The bridge is in the poor condition, mainly because of significant corrosion in the main structural members. The paper describes the assessment of the bridge, including the corrosion survey, and the results of the structural analysis.

One of the most important load types was the wind load, because of the slenderness of the bridge. It was observed, that wind load acting of the bridge and the train induces high forces in the lower and upper chord. Those forces reduce the free space for the train load itself. Because of that, the wind tunnel testing was used to decrease the load level by designer, but despite the reduction, the bridge did not satisfied as well. The results are described together with the wind tunnel results.

The second part describes the interesting behavior of the bridge, exposed to the wind load, with the connection to the corrosion weakening. It was noticed, that the corrosion weakening of the horizontal deck bracing has significant impact on the redistribution of the axial forces in the truss. With high level of weakening, the tensile forces from the wind in the lower chord increased significantly, because of the stiffness change. This impact was very severe and surprising. The parametric study was thus performed and the results are discussed, together with the recommendations for the praxis.

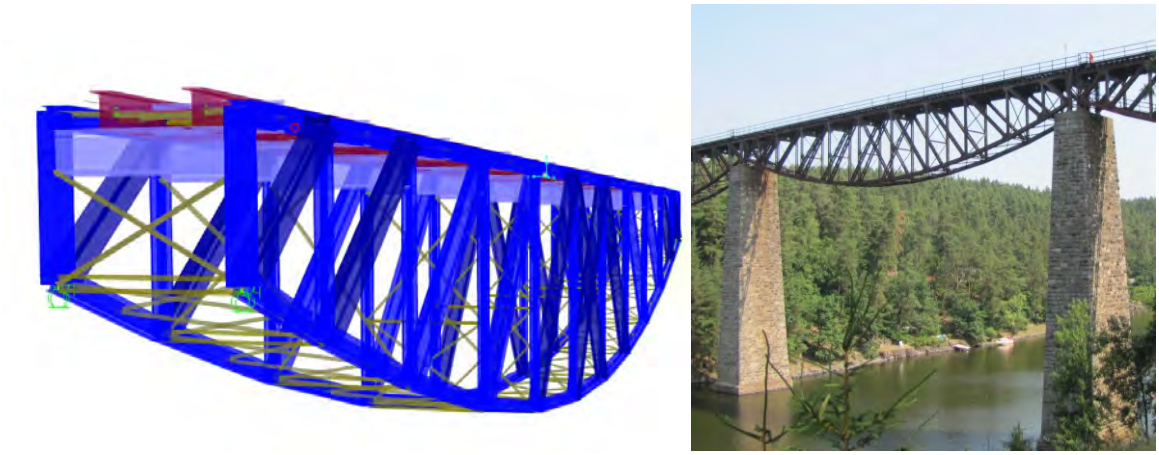

Figure 1 – *The model for the structural analysis (left) and the real bridge (right)*

#224 The dynamic behavior of the extremely skew railway bridge „Oskar“

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Abstract The paper describes the behavior of the new railway bridge in the Czech Republic, located on the track between Hohenau and Přerov. The bridge is a net arch structure of span 97.5 m and skew angle 43°. The bridge is equipped with the steering bar Meyer – Wunstorf, because of the reduction of the stresses in the track, caused by the train-bridge interaction. Those unique features led to the throughout dynamic analysis and testing. The paper describes the results of the numerical model, where the bridge response to the trains with speed of up to 160 km/h was analyzed. The first results were not successful, as the transversal vibrations induced significant exciting of the tension bars. Thus several modifications had to be done, such as ballast weight, stiffening of the structure etc. Also, the impact of the skew supports was analyzed on the parametric study on various models with different angles. After the construction of the bridge, several extensive load tests were performed here. First, the dynamic load test was performed, consisting of the passing of the bridge with heavy locomotives and coal coaches, of total weight of 974 t. The test was mainly focused on measurement of strains in the bridge, the rail, the measurement of acceleration on the girders, arches and tension bars and evaluation of the basic natural frequencies and mode shapes. The last tests were the brake and acceleration tests focused on verification of the function of the steering bar system.

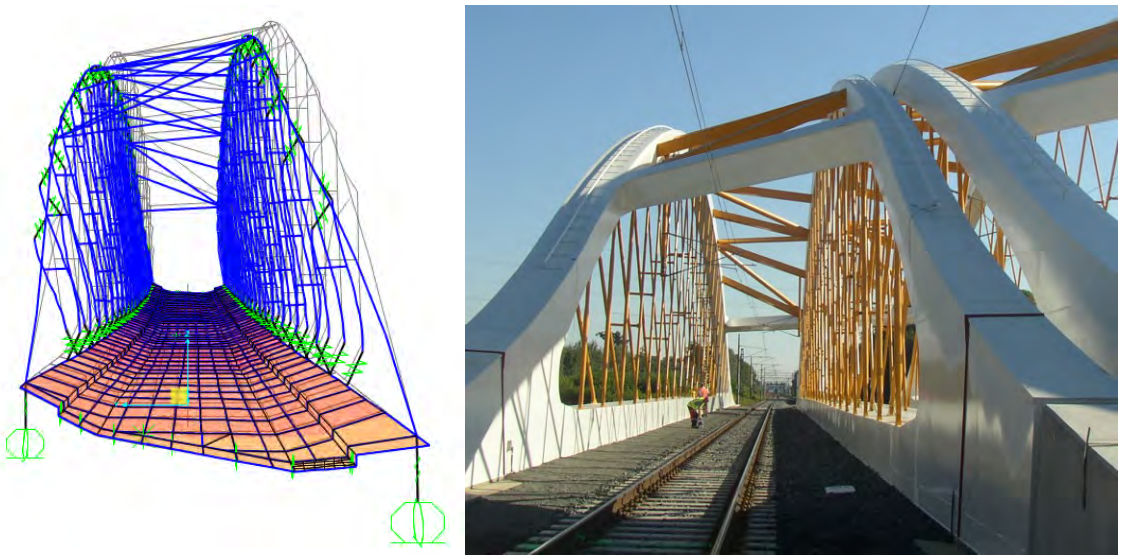

Figure 1 *– The model for the dynamic analysis (left) and the finished bridge (right)*

#225 Stable crack growth in composite laminates under various stiffness of the loading system

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Abstract. The work is devoted to experimental study of stable and unstable crack growth processes in composite materials. The eccentric tension tests of compact specimens of composite laminates in conditions of different stiffness of the loading system were carried out. During the analysis of test results, descending sections of the loading curves were considered by analogy with postcritical deformation stage, which could be found in test of smooth specimens of different materials. Postcritical deformation stage connected to the accumulation of damages, structural failure and fracturing processes and each point on this stage can correspond to the moment of the loss of load-carrying ability because of transition from stable to non-equilibrium process of damages accumulation, which depends on stiffness of the loading system. For studying of crack growth processes in composite laminates, the eccentric tension tests of compact specimens (fig. 1, *a*) at room temperature were carried out. The specimens with notch and with initial fatigue crack were used. The servohydraulic test system Instron 8801 (±100 kN, 30 Hz) with COD gauges and axial dynamic extensometers were used in tests. Loading curves (fig. 1, *b*) in terms of axial load *P* (kN) and crack opening displacement *u* (mm) were obtained in tests for various stiffness of the loading system.

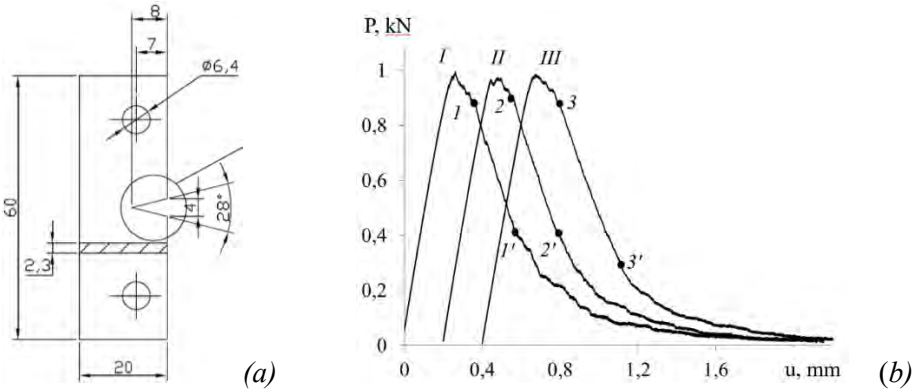

Figure 1 *– Sketch of specimen (a) and loading curves in the tests with different stiffness of loading system (b)*

Testify to the fact that behavior of specimens with crack on the descending section of loading curve during the crack growth depends on the loading system stiffness, which reflected in various crack growth rates. In case of not-sufficient stiffness, the crack can grow in non-equilibrium regime that should be taken into account when analyzing of structural integrity in real loading conditions.

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

#226 Optimal Cruciform Specimen Design Using the Direct Multi-search Method and Design Variable Influence Study

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Abstract Nowadays the development of new testing machines and the optimization of new specimen geometries are two very demanding activities. In order to study complex material stress and strain distributions, as in-plane biaxial loading, one must develop new technical solutions. A new type of testing machine has been developed by the present authors, for the fatigue testing of cruciform specimens, but the low capacity of the testing machine requires the optimization of the specimen in order to achieve higher but uniform stress and strain distributions on the specimen center. As the specimen geometry requires several design variables to be fully defined, complex optimization algorithms must be used in order to obtain the desired results.

In this paper, the authors describe the procedure to optimize one possible geometry for cruciform specimens, able to determine the fatigue initiation life of material subjected to out of phase in-plane biaxial fatigue loadings. The cruciform specimen geometry is defined with an elliptical corner fillet and the central thickness is reduced using a revolved spline cut. The high number of design variables were optimized using the direct multi-search method, considering two objective functions, the stress level on the specimen center and the uniformity of the strain distribution on a 1.0 mm radius of the specimen center. Several Pareto Fronts were obtained for different material thickness, considering the commercially available sheet metal thickness. With the optimal solution, the influence of every design variable was studied in order to provide others with a powerful tool that allows selecting the optimal geometry for the desired application.

The results are presented in the form of design tables and design equations considering that the main design variable, the material thickness, was chosen from a Renard series of preferred numbers. The end user is then able to configure the optimal specimen for the required fatigue test.

#227 Fatigue life and damage accumulation assessment under random and variable amplitude multiaxial loading conditions

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Abstract: Fatigue damage and life assessment of multiaxial loadings is still an issue yet to resolve. Many methods have been proposed with promising agreements with the experimental results. However, the performance of such methods is, more than often, purely based on fatigue tests with simple loading conditions. In this work the stress scale factor (SSF) criterion and the virtual cycle counting (vcc) method are used to estimate fatigue life and damage accumulation with two damage accumulation rules. Fatigue tests were carried out with three different variable amplitude random loadings, applied to several specimens made from a 42CrMo4 high-strength steel. The applied methods provided very acceptable results making the SSF package (SSF equivalent stress and virtual cycle counting method) a good method to estimate fatigue life and assessment of the damage accumulation in random fatigue loadings.

#228 Anomaly detection in composite elements using Lamb waves and soft computing methods

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Abstract Composite materials are widely used in many responsible structures, which in turn entails the need to develop sensitive and reliable structural health monitoring (SHM) systems. The aim of this study was to investigate the use of guided waves and artificial neural networks as essential components of a two-stage diagnostics system. This system was designed to detect anomalies and to assess their parameters. This paper presents the first result of the application of this system for evaluation of samples made of composite materials. Defects of various origin were artificially introduced. Grids of 8 and 12 piezoelectric transducers were used. Principal components analysis was used for dimensionality reduction of measured signals. Examples of preliminary fault detection results were shown that any signal anomalies are detected perfectly whereas the prediction of damage level allowed to distinguish the defects introduced. Successful experiments carried out on the studied specimens have already proved that this system was able to perform automatic analysis of the elastic waves and accelerate the process of structures diagnosis.

#229 Force identification in bolts of flange connections for structural health monitoring and failure prevention

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Abstract Force identification in bolts of flange connection is not only important to preserve the structure integrity but also to understand and verify code procedures. Due to the relaxation phenomenon it becomes even more important in case of compressed bolts. In this paper a series few of bolted flange connections were examined during static tensile tests. Only selected bolts were equipped with tensile force sensors. Alternatively some bolts were equipped with piezoelectric transducers (actuator and sensor) in order to measure signals of elastic waves. It was noted that the load increasing causes changes in the signals measured. Principal components analysis was used for dimensionality reduction of measured signals. The aim of this study was to investigate the use of elastic waves and artificial neural networks for the purpose of force identification. Examples of preliminary results have shown that force in each bolt may be estimated with relatively good accuracy.

#231 Preserving European paintings in Asianenvironment. The case of Goa Cathedral former altarpiece.

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Abstract How to preserve a set of paintings made with European materials and taken to South Asia in the 16th century? A set of seven paintings belonging to the first altarpieceof Goa Cathedral now remain in its sacristy. Art history states that these paintings, assigned to the painter Garcia Fernandes, were produced in Lisbon circa 1530 and carried to Goa shortly after[1-3].Presently, the conservation state of the paintings indicates urgent treatment. The most damaged paintings show significant loss of the original chromatic layer. This is mostly due to the high temperatures and relative humidity existing in tropical climates, such as Goa, different from the European environment. On the support of Baltic oak are the ground layers of calcium sulphate that, with the contractions of the wood, suffered great losses and fissures. The high reactivity to water of the ground materials is also a factor leading to specific material deterioration and degradation mechanisms. In comparison with the paintings of the same period produced in Portugal using the same materials, we verify a much higher degradation of the state of conservation. To access the procedures for preservation and restoration of this set of paintings we must take into account the possible degradation mechanisms of the constituent materials brought by specific environmental factors. This presentation intends to discuss the degradation problematic of this specific set of paintings taking into account their particular environment, while bringing results on the materials used. Concluding, this study will allow the knowledge on how to preserve and restore one of the most ancient sets of European paintings in India, kept since the 16th century in tropical climate.

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#234 Processing steady thermographies by topological derivative methods

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Abstract Active infrared thermography is a promising means of nondestructive testing with a broad range of applications that include building and medical diagnosis, and night vision, to mention a few. In comparison with other nondestructive techniques, as ultrasonic testing, it is safer and more nonintrusive and noncontact. But, on the other hand, heat transport is short range, and that the associated signal to noise is less favorable than in other techniques. To alleviate these drawbacks, we propose in the present work to efficiently process thermographic data by using topological derivative based methods. The topological derivative can be seen as an indicator function that classifies each point of the observed region as either belonging to one defect or to the background media. This tool has been successfully used in two dimensional thermal propagation problems [1]. In this work, we will use it to process steady thermographies, where the available data is just one thermography or various in case several different positions of the lamp where the heat is emitted are considered. We will show that the topological derivative corresponding to several positions of the lamp can be efficiently combined to improve the results by implementing some ideas proposed in [2].
Some numerical examples for 3D steady thermographies corresponding to flawed aluminum plates will be shown.

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#235 Measurement of Dynamic Fracture in Hot Forming Processing: Effect of Steel and Temperature

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Abstract: Under the combined influence of a thermal and applied stress, engineering thermoplastics may undergo a phenomenon known as thermomechanical fatigue or as environmental stress cracking. The mechanisms of fatigue propagation are examined with particular emphasis on the similarities and differences between cyclic crack growths in hot forming processing materials. The influence of damage on the intensity of the destruction of materials is studied as well. The fracture of hot forming processing materials subject to high thermal and mechanical loadings rates is notably affected by material inertia. At high loading rates, tiny fluctuations in the plastic flow field induce important acceleration of materials particles. This, significant inertia effects are taking place at the macroscopic level and sometimes also at the level of microscopic deformations mechanisms. Numerical simulations of crack propagation in cylindrical specimen based on Finite Element Analysis (FEA) by ABAQUS Software, demonstrate that the proposed method provides an effective means to simulate dynamic fracture in large scale cylindrical structures with engineering accuracy.

Keywords: Damage, thermomechanical Fatigue, Dynamic fracture, Hot forming processing

#236 Characterization of the Tensile Mechanical Behavior of Wooden Construction on Materials from Historic Building

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Abstract Ancient structures are part of the inheritance our elders left us. These historical inheritance needs to be preserved, so the historic structures need to be rehabilitated and restored, protecting the cultural patrimony and attending to the comfort and habitability required nowadays. In order to accomplish a good and economic rehabilitation is essential to study the behaviour of traditional structures elements (masonry and wood) in order to develop adequate assessment measures and techniques. In this context it was carried out an experimental campaign to characterize the tensile mechanical behavior of the woods from the "sequeiro" wood structure, integral part of the "Quinta de Lobeira de Cima" farm. This building from the 20th century is located in Minho, Portugal. Tensile Tests were carried out for two different species of wood, chestnut and oak. The tensile tests were performed to obtain the tensile strength parallel to the fibers, using the digital image correlation (DIC) for the extension measurement.

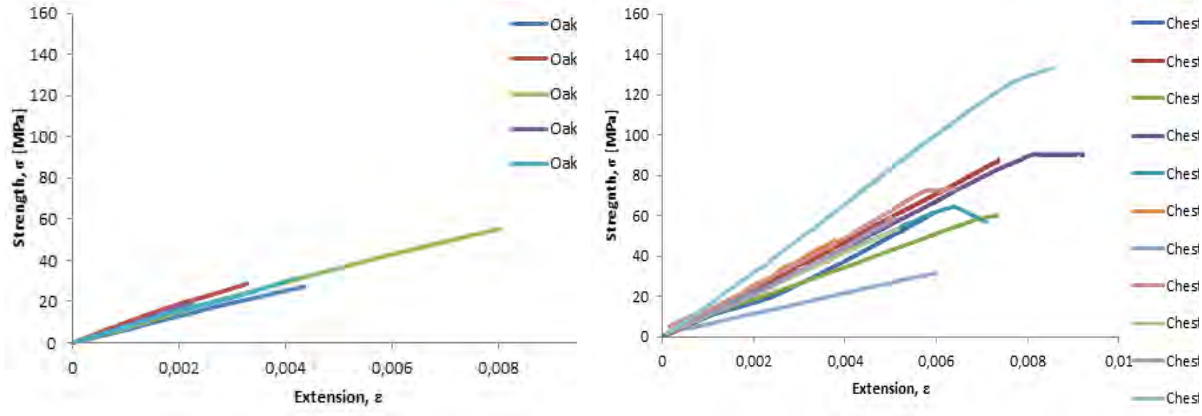

Fig. 1. Strength versus extension curves resulting from parallel to the fibers tensile testing: (a) oak specimens; (b) chestnut specimens.

#237 Structural Integrity Evaluation of the "Constitución de 1812 bridge", over the Cádiz bay (Cádiz, Spain)

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Abstract As required by the latest regulations, an inspection and maintenance plan has been drafted for "Constitución de 1812 bridge over the Cádiz bay" (Cadiz), which defines the tasks to be performed in the different elements of the bridge during its useful life. In the part related to the inspection of the steel structure has a section dedicated to the inspection of defects or notches that can be produced in the steel deck, providing critical crack sizes above which would compromise the safety of the structure. For this, in the most stressed points of the board, the construction details more susceptible to phenomena of fatigue and appearance of fissures have been identified. Fatigue tests of these details have been performed to complete a structural integrity study to determine the fracture toughness of the material and the critical crack size. The tests were carried out on specimens obtained with the same materials (grades of steel) used in the bridge and with the same welding procedures practiced in the structure. The results show that critical crack sizes are around 12 mm, with structural details with critical crack sizes of only 6 mm.

#238 Petrographic Characterization of Partition Wall Mortars of a 19th Century Building

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Abstract To correctly rehabilitate of a structure, it's necessary a rigorously diagnose of pathologies of the building structures, defining the conservation state and the impact that the identified pathologies have in the structure safety. The present work is focused in a petrographic study of mortars of aerial and hydraulic lime used in lime and gypsum plaster from a structure from the 19th century existing in Felgueiras town in Portugal, representative of the buildings of that period in this town. The mineralogical composition of the mortars is of high importance to understand it's mechanical behaviour and water absorbing behaviour, so can be taken measures to stop the main problems that may occur in those mortars and consequently on the structures. The case study building is a typical masonry structure building with lime mortars, with wood floors and gabled roof inserted in a region with an annual moisture index of 80% and near some water tanks. It shows sign of determination caused by the capillarity and infiltration among other pathologies.

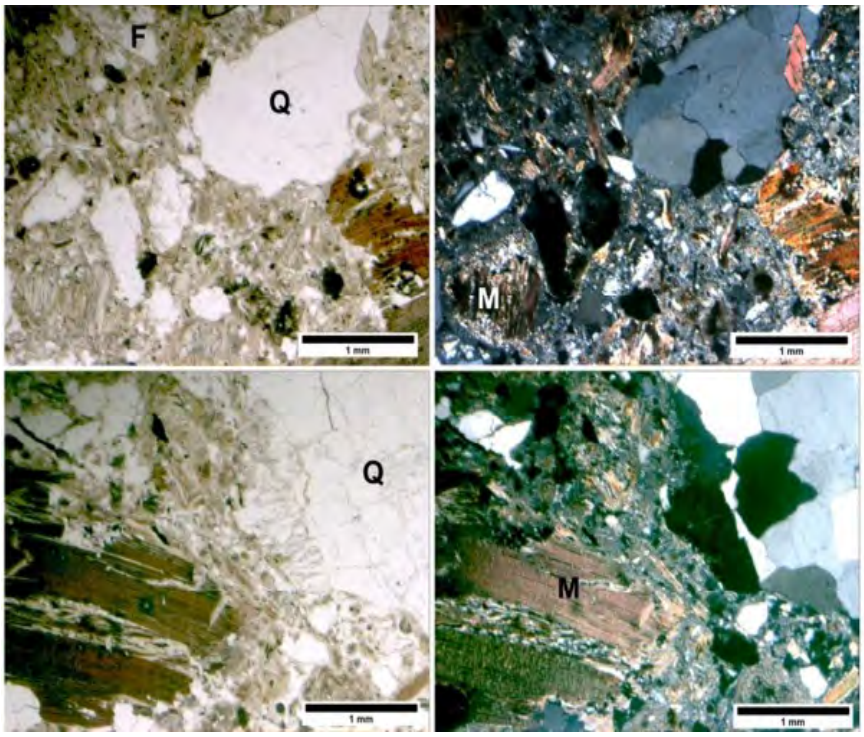

Figure 1 - *Petrographic aspects of the 1st layer, in the left the images were obtained for natural light and in the right with polarized light (F – feldspars; M – micas; Q – quartz)*

#239 Mechanical properties of Wood Construction Materials from a Building from the 19th Century

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Abstract This paper presents the results obtained in an experimental campaign fulfilled in a eucalyptus wood beam removed from a roof structure of a masonry building of the 19th century, located in the North of Portugal. Several specimens were extracted from the eucalyptus wood beam for testing under tensile properties parallel to the fibers, compression properties parallel to the fibers and flexural properties. It was also determined its density and water content. Using the Gauss normal distribution were obtained the characteristic values (lower percentile of 5%) of the parameters obtained experimentally. With the characteristic value of the wood density it was possible to obtain other parameters using empirical formulas such as the tensile strength perpendicular to the fibers, the compressive strength parallel and perpendicular to the fibers, the shear strength and flexural strength.

Table 1 - *Results of the characteristic values obtained experimentally and empirically.*

Properties	Symbol	Values
Characteristic density (Kg/m^3)	$\rho_{g,k}$	718,59
Tensile strength parallel to the fibers (MPa)	$f_{t,0,g,k}$	55,14
Tensile strength perpendicular to the fibers* (MPa)	$f_{t,90,g,k}$	6,68
Compressive strength parallel to the fibers(MPa)	$f_{c,0,g,k}$	30,92
Compressive strength parallel to the fibers* (MPa)	$f_{c,0,g,k}$	33,95
Compression strength perpendicular to the fibers* (MPa)	$f_{c,90,g,k}$	8,15
Shear* (MPa)	$f_{v,g,k}$	11,82
Flexural strength (MPa)	$f_{m,g,k}$	77,24
Flexural strength* (MPa)	$f_{m,g,k}$	80,90

Note. * Empirical analysis

#240 Fatigue behavior and material characterization of butt welded joints in a high strength steel (class 700 MPa)

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Abstract Is improving daily and the need to manufacture new materials is increasing. Therefore is necessary to collect the maximum information as possible from the new material. One of the many information that can be retrieved is the behavior of the weld when is subject to fatigue loadings. The objective of this work is to evaluate the fatigue strength of a high strength steel (class 700 MPa) under stress ratios of R = 0.1 and R=0.5 and estimate the fatigue strength of welded plates with 4 different sets of welding parameters under the same stress ratios. For each set of welding parameters were tested 3 different geometries for the weld: a geometry that causes the propagation of the crack in the heated affected zone (HAZ), a geometry where the weld is perpendicular to the crack propagation direction and finally a geometry where the weld is parallel to the crack propagation direction. The Paris Law was determined for each test to estimate what was the geometry and welding parameters that presented a higher fatigue strength. Another objective of this work is to assess the variation on hardness and stiffness along the weld zone and study the influence of the 4 different sets of welding parameters on the same proprieties. It was also study the steel microstructure in different zones that appeared due to the welding process and it was compared with the microstructure of the base material. Finally, experimental tests were performed to evaluate the corrosion resistance and wear resistance of the samples with different sets of welding parameters.

#241 Pathological Inspection of Structural Masonry Walls of a Late-Romantic Historical Building

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Abstract The present work, has the objective of increase and encourage the rehabilitation of historical buildings, through the presentation of structural and pathological inspection, using techniques as thermometer and humidimeter to assess the conservation state of the structural elements of a 19th century building existing in Felgueiras, Portugal. The structural members' main problems identification makes it easier to predict their behavior and develop rehabilitation solutions to the problems.

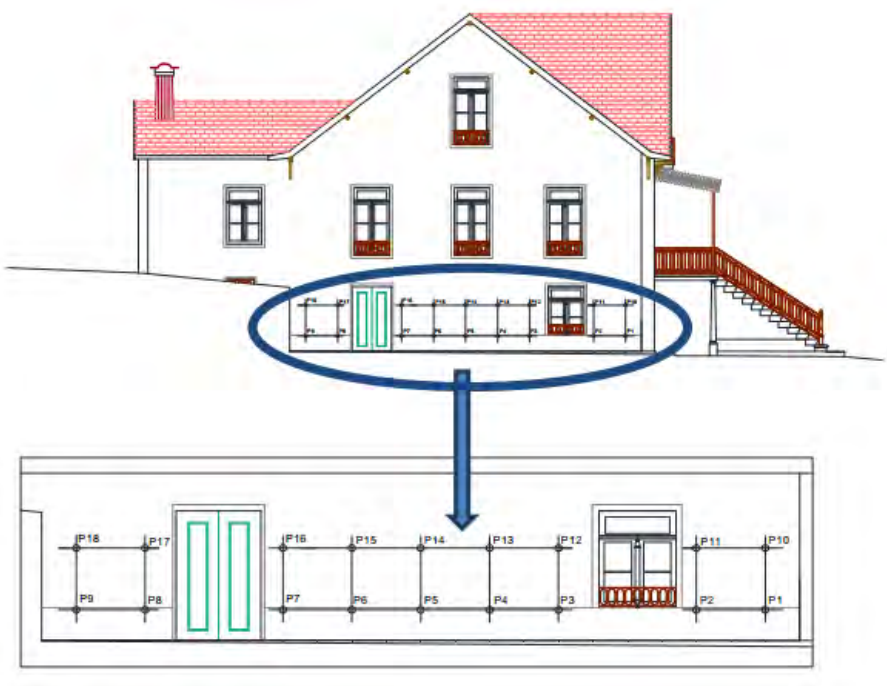

***Figure 1** – Spatial points network used to measure the humidity and temperature.*

#243 Comparison of the fatigue behaviour of AA6082-T6 and AA6061-T651 aluminium alloys

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Abstract It is widely known that in the last decade's aluminium alloys have been more and more used in the production industry. The AlMgSi aluminium alloys have moderate to high strength. However, if the weight/strength concept is taken into account, it can be concluded that they present advantages in some domains of engineering applications such as a good corrosion resistance and high toughness combined with good formability and weldability. These properties are commonly used as advantages in the manufacture of heavy-duty structures in mechanical engineering, namely, in shipbuilding, bridge building, railroad cars, furniture, tank fittings, general structures, high pressure applications and others applications used in the metallurgical industry.

This study presents the main results of an investigation carried out with two AlMgSi age-hardened materials, namely the 6082–T6 and 6061-T651 aluminium alloys. These alloys are generally considered to be similar. The 6082–T6 aluminium alloy is mainly used in Europe while the 6061-T651 aluminium alloy is most popular in the USA.

Low cycle fatigue and fatigue crack propagation tests have been performed in the two heat-treated AlMgSi aluminium alloys under constant amplitude loading. The influence of spike overloads was also analysed. All experiments were performed, in load control, in a servo-hydraulic closed-loop mechanical test machine. The influence of stress ratio and thickness were analysed on fatigue crack growth. Crack closure was monitored in the tests by the compliance technique using a pin microgauge. A strong stress ratio and material dependence effects on the fatigue crack growth were observed. The crack growth behaviour of heat-treated aluminium alloys depends mainly on whether the dominant closure mechanism is plasticity-induced or roughness-induced. The enhancement of roughness-induced closure promotes higher crack growth resistance in these alloys. Roughness-induced closure dominates crack closure in 6061-T651 alloy, while in 6082-T6 aged hardened alloy plasticity-induced closure is dominant.

Keywords: Damage Tolerance; Structural Integrity.

#244 Plasticity induced closure under variable amplitude loading in AlMgSi aluminium alloys

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Abstract Service conditions generally involve random or variable amplitude, rather than constant amplitude loads. Significant accelerations and/or retardations in crack growth rate can occur as a result of these load variations. Thus, an accurate prediction of fatigue life requires an adequate evaluation of these load interaction effects. To attain this objective several type of simple variable amplitude load sequences must be analysed.

Several mechanisms have been proposed to explain the crack growth transients following variable amplitude loading sequences, which includes models based on residual stress; crack closure; crack tip blunting; strain hardening, crack branching and reversed yielding. However, the precise micromechanisms responsible for these phenomena are not fully understood.

In spite of some controversy, the effect of residual plastic deformation, which leads to compressive stresses before the crack-tip and raises the crack opening load on subsequent crack growth (crack closure), has been identified as the most important aspect in explaining the characteristic features of crack growth retardation.

The present work intends to analyse the crack closure levels on aluminium alloy specimens subjected to several variable amplitude loading sequences and evaluate if the observed transient crack growth behaviour can be correlated with the crack closure phenomenon.

For this purpose, fatigue crack propagation tests have been performed in 6082-T6 aluminium alloy under peak overloads, periodic overloads, as well as High-Low (Hi-Lo) and Low-High (Lo-Hi) block loading sequences. All experiments were performed either in load control or in constant ΔK conditions, in a servo-hydraulic, closed-loop mechanical test machine, interfaced to a computer for machine control and data acquisition. The tests were carried out using Middle-Tension 3 mm thick specimens and were conducted in air, at room temperature and with a load frequency of 20 Hz.

The observed transient crack closure level is discussed in terms of loading sequence, load change magnitude, ΔK baseline levels and intermediate baseline cycles. The crack closure level is compared with the crack growth transients. A good agreement between experimental and predicted crack growth rates is obtained when the partial crack closure effect is properly taken into account. Therefore, plasticity-induced crack closure plays an important role on the load interaction effects observed in aluminum alloys.

Keywords: Damage Tolerance; Structural Integrity.

#245 Analysis of fatigue crack propagation in laser sintering metal based on plastic CTOD

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Abstract Laser sintering metal (LSM) has recently been used in the manufacture of components for different applications like aerospace or medicine. Many studies, mainly focused on the influence of sintering parameters and selection of metal powder on microstructure of the sintered parts, state that for some materials, LSM parts are able to offer static mechanical properties comparable to the properties of conventionally bulk materials. In service the components are typically dynamically loaded, for which additional work is needed to fully understand the fatigue behaviour and the relevant control parameters. The approach to engineering design based on the cracks propagation assumption applying the concepts of linear elastic fracture mechanics (LEFM) is commonly used for aerospace engineering. However, fatigue crack propagation is linked to irreversible and non-linear mechanisms at the crack tip, therefore LEFM parameters have be successfully replaced by non-linear crack parameters namely the plastic CTOD.

The main purpose of the present work is to define a da/dN versus plastic CTOD relation for the laser sintering AISI 18Ni300 maraging steel. Fatigue crack propagation, da/dN, was obtaining, in agreement with ASTM E647 standard, using 3 mm thick compact specimens. A numerical study was subsequently defined, replicating the experimental procedure in order to obtain the plastic CTOD. The numerical model intended to be realistic in terms of geometry of the specimen and crack, in terms of loading and in terms of material behaviour. The accurate modelling of material hardening is of major importance for the quality of numerical predictions. The behaviour of the material was obtained from low-cycle fatigue experimental tests with smooth specimens tested under constant amplitude strain range. The stress-strain loops were used for the analytical fitting of hardening models. Finally, the da/dN versus plastic CTOD model was used to predict fatigue crack propagation for different load patterns, namely overloads, underloads and load blocks.

Keywords: Numerical modelling; Damage Tolerance.

#246 Risk based planning of assessment actions for fatigue life prediction

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Abstract This paper if focused on enhanced methods for fatigue assessment, on actions and measures that can be taken when a conventional assessment indicates an exhausted fatigue life. Extending the service life of existing bridges as far as possible is motivated in general for sustainability reasons to minimize economic cost and resource consumption. Furthermore, it can be a necessity for bridges with a critical position in highly stressed infrastructure systems where replacement would cause serious traffic disturbance.

An enhancement of the fatigue assessment can involve different actions and methods influencing different aspects of the process. This paper presents a framework based on three factors to categorize the actions; (i) model sophistication, (ii) uncertainty consideration, and (iii) knowledge content. Following this framework, the influence of different actions on the assessment process becomes obvious and a strategy for the enhancement can be determined. Furthermore, it provides a basic scheme for a risk based decision analysis on what assessment actions to encompass.

The assessment framework based on the three factors is presented in the paper together with a description of the risk based decision analysis. The whole procedure is applied to a case study of a steel bridge in Sweden prone to fatigue deterioration carrying railway traffic.

#247 Numerical study of fatigue cracks propagation in butt welded joints in a high strength steel (class 700 MPa)

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Abstract Nowadays material characterization is an important task in manufacturing field. Therefore, numerical models are required to simulate the real mechanic material behaviour without wasting. The stress intensity factor (K) is an important parameter for estimating the life of the cracked structure. The main goal in this work is evaluate the fatigue strength of 4 high strength steel (class 700 MPa) samples with different welding configurations under stress ratios of R = 0.1 and R=0.5. In order to analyze the geometry effects on the fatigue strength, simulations were made using Abaqus Software in each sample. At first, the stress intensity factors, K, have been calculated on a static analysis using extended finite element method (XFEM) in Abaqus Software, the results were compared with the theoretical values. Then the fatigue crack growth was simulated using the XFEM in Abaqus software on a dynamic analysis, computing the different stress intensity factors for different crack lengths. The fatigue crack growth curve was made accordingly with the Paris Law with the crack length variation vs number of cycles. The best configuration in welding position was determined by the highest fatigue crack strength. Finally, the results were compared with the experimental values to realize the numerical study accuracy.

Key words: Stress intensity factors, Extended finite element method, Abaqus, crack propagation, fatigue crack growth

#248 A Generalization of Neuber's Rule for Numerical Applications

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Abstract In this paper a generalization of Neuber's rule for a quick and easy elastic/plastic notch analysis is proposed and discussed. The proposed generalization allows numerical and/or graphical solution for any notch geometry and its associated stress concentration factor, k_t, and /or fatigue notch factor, k_f. It is shown, that so called Neuber's "master" curve, involved in such analysis, is unique and is only material dependent. The "master" curve is obtained by simultaneous solution of Ramberg-Osgood relationship and Neuber's rule, then plotted (Fig.1) in terms of the product of nominal stress, S, times stress concentration factor, k_t (or k_f), versus the actual notch root strain, ε. The Neuber's "master" curve is interactive and is applicable for both monotonic and cyclic loading situations. The present formulation is pertinent to situations when applied nominal stresses, S, is below the material yield stress, σ_0, i.e. $S \le \sigma_0$. Examples of applications of the proposed method are presented in terms of fatigue life predictions and material screening for optimal design of components containing notches.

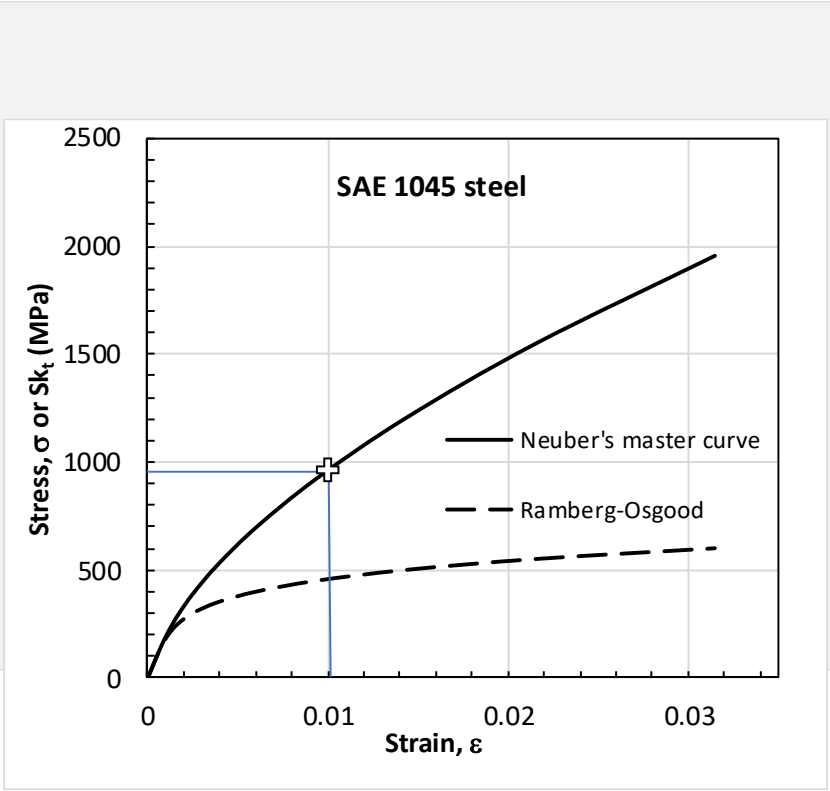

***Figure 1** – Ramberg-Osgood and Neuber's "master" curves.*

#249 Stress concentration around circular holes in carbon-fibre reinforced polymer composites

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Abstract For a thin and semi-infinite plate subjected to a uniaxial tensile stress state, a through hole induces a theoretical or geometrical stress concentration factor equal to 3. This value increases to 4 for a pure shear stress state and decreases to 2 for an equibiaxial stress state. However, it is only valid for isotropic materials. In the case of anisotropic materials, such as fibre-reinforced polymer composites, the stress concentration factor could be greater or lower than the values. In addition, the points where the maximum stress values arise could be shifted when the fibre orientation changes with respect to the loading axis. Considering the case of carbon-fibre reinforced polymers (CFRP) as the reference, the stress concentration due to small holes in composite plates subjected to different stress states is analysed. The stress concentration is determined for through and blind holes, studying its evolution with the hole depth. The effect of the ply orientation and the stacking sequence is analysed with the objective of minimizing the stress concentration factor. It is shown that the stress concentration effect can be reduced by the lamination process and a consequent improvement in the structural performance of the composite system is possible. The results presented in this study only consider the case of plates with eight plies, stacked together in the following arrangements: $[0º]_8$, $[90º]_8$, $[+45º,-45º]_{2s}$ and $[0º,90º]_{2s}$, subjected to different stress states. Although this study is numerical, using the finite element analysis (FEA) technique, comparison with theoretical models is carried out whenever possible.

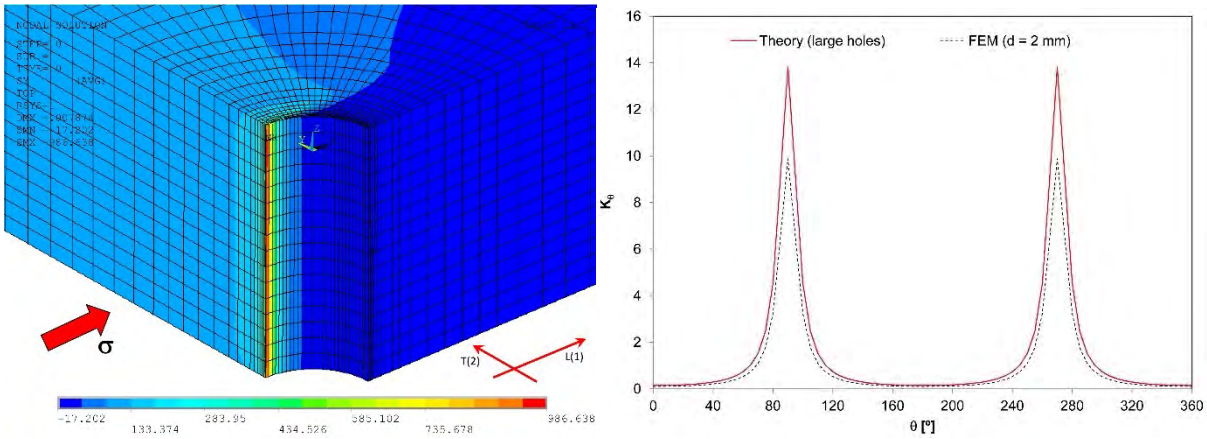

Figure 1 - *Numerical tangential stress (σ_θ) distribution around a through hole (stress ofreference σ=100MPa and α=0º) in a single ply of carbon-epoxy plate (left). Comparison between the numerical and theoretical value of $K_\theta = f(\theta)$ (right)*

KEYWORDS: Numerical modelling, Design and Structural Assessment

#251 Advances on the use of non-destructive techniques for mechanical characterization of stone masonry: GPR and sonic tests

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Abstract The main aim of the present work is to use NDT (non-destructive test) for characterization of stone masonry and obtain information regarding the mechanical parameters. Due to historical and cultural value that historic buildings represent the maintenance and rehabilitation work is important to keep the appreciation of history. The preservation of buildings classified as historic and cultural heritage is of social interest, as it marked the history of society. Considering the object of research as a historic building, it is not recommended to use destructive investigative techniques. This paper focuses on the application of geophysical method Ground Penetrating Radar (GPR) and sonic tests for civil engineering purposes as NDT research option. The GPR is composed of a receiving antenna and a transmitting antenna that emits electromagnetic waves into the subsurface and generates a characteristic radargram of the considered area. The sonic tests are performed with an instrumented hammer and accelerometers for reception waves, these can be P, R or S. Through this work, it is possible to understand the behavior of two-leaf stone masonry by relating the NDT' parameters with mechanical properties. To assist this analysis, the compression test' results will be used. Simultaneously to the application of NDT's were made on the stone masonry destructive tests, like compression tests, to obtain compressive strength, Modulus of elasticity and Poisson's ratio. These data will be correlated with the NDTs' results. The use of other technique in line with the GPR method is widely used in order to address deficiencies of the GPR. The GPR presented radargrams suitable for the structural type constitutive of the walls and the points identified with the presence of more resistant structural elements, validate the results obtained by the sonic tests. With the sonic tests' results is possible to calculate values of Poisson's ratio, the Young's modulus and shear modulus, to characterize the material. For the sonic tests, it is indicate that the higher velocity points are those from the direct test made on the header block. The sonic test resulted in characteristic values of propagation velocities of the sonic waves in the analyzed walls, with these results obtained values of Modulus of elasticity that supported the mechanical tests. In this way, it is highlighted that the synergy of the tests provides more coherent results for future correlations with the mechanical data. Both NDTs used presented coherent and related results, one technique corroborating the results of the others. The correlation between mechanical parameters and NDTs' results will be investigated resorting to artificial neural networks' techniques (ANN), which is the next step of this work.

#252 DIC Study of Cycle-Sequence Sensitivity of Fatigue Crack Closure

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Abstract The close relationship between sequence-sensitive near-tip residual stress, threshold and crack opening stress intensities raises questions about load interaction models to estimate fatigue crack growth under variable amplitude loading. The discovery of the close relationship between σ*, and closure free ΔK_{th} [1] gives a new understanding of the residual stress effect in metal fatigue. It is obvious that the monotonic plastic zone plays an important role, but it is one that will be modulated on a cycle-by-cycle basis by near-tip stress-strain response to load history. In previous work [2,3] it was shown that crack closure, near-tip residual stress (through associated ΔK_{th}) and crack-tip blunting together determine near-threshold fatigue crack growth response to overload-underload sequences. But the recovery of crack closure in case of various load sequence was not clearly assessed by experiment. Moreover cycle-sequence sensitivity of ΔK_{th} is revealed only when the crack is fully open over baseline cycling, so in the absence of visible cycle-sequence sensitivity, the effect of increased ΔK_{th} may be wrongly attributed to closure. This opens the possibility of new experiments specifically targeting the relationship between crack-tip blunting/resharpening and closure transients after applied overload-underload cycles. Additionally, it could throw more light on the individual contribution of both increases in near-tip stresses and crack closure.

In order to address these ambiguities the digital image correlation (DIC) technique is implemented for in situ crack closure measurements, including crack closure/opening levels along the wake, material response on the applied loads in the plastic and elastic zones ahead of the crack tip. Fatigue crack growth tests were performed on compact tension and on single edge crack tension specimens made of Al-Cu alloy under specially designed load sequences. Current study demonstrates the crack closure variation along the crack wake, the changes caused by single overload and underload cycles or their combinations. Obtained results are compared with conventionally used models for crack closure in engineering applications.

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[2] R. Sunder et al, Combined action of crack closure and residual stress under periodic overloads: A fractographic analysis, Int. J. of Fat., 82 (2016) 667–675.
[3] R. Sunder et al, Synergy of crack closure, near-tip residual stress and crack-tip blunting in crack growth under periodic overloads – A fractographic study, Int. J. of Fatigue 93 (2016) 18–29.

#253 Crack control in concrete using shock wave techniques

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Abstract Cracking is commonly observed in reinforced concrete structures during their service life. Crack formation significantly reduces the stiffness and strength properties of concrete. One of the methods to restore cracked structural concrete is epoxy injection of cracks. The effectiveness of this technique is supported by the fact that new cracks appear outside the region of repaired cracks.

This paper focuses on further development of the nondestructive shock wave method used in structural engineering to control concrete state at service loads, as well as during its repair after first cracking. The method is based on registration of wave processes occurred in concrete due to impact loading and comparison of these processes for undamaged and cracked structures.

The proposed variant of the method allows registration of elastic shock wave parameters at instants when they are practically independent of structure fastening conditions and respond most adequately to the presence or absence of a crack.

The capabilities of the method are illustrated by changing the behavior of a reinforced concrete beam with a crack at different stages of its formation and elimination. Numerical simulations provide a means of analyzing parameter changes in the wave front passing through a region of the crack. A quantitative criterion is formulated to assess whether the examined concrete is undamaged or there are cracks in it. Also it can be used to determine how the state of a crack changes at increasing load and at the stage of its elimination. This criterion is defined as the ratio of acceleration amplitudes of first half-waves registered in areas on both sides of the crack. The value of the criterion does not depend on impact load amplitude and beam fastening conditions and is determined only by the mechanical state of the material used to heal the crack.

The results of numerical modeling are compared with experimental data to validate the adequacy of the proposed criterion. It is shown that the value of the criterion depends on the location of points, at which accelerations are registered. Results obtained from a cycle of numerical experiments yield optimal distances between the pulse application point and the acceleration registration areas, where the criterion exhibits the best sensitivity to the state of a crack. The efficiency of the developed method for controlling the state of a crack in the process of its restoration with a repairing material is demonstrated.

#255 Statistical Analysis of the Influence of Several Factors on Compressive Strength of Alkali Activated Fly Ash

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Abstract The use of industrial by-products to produce new types of cement-substitute binders is gaining significant momentum, especially through the alkaline activation technique. However, the exact curing conditions that should be considered with each binder variation have not yet been fully understood. The aim of the present work is thus the statistical analysis of the effects of several factors, namely filler/precursor ratio and curing humidity, on the compressive strength of different mixtures prepared with mine tailings (filler), fly ash (precursor) and an alkali activator based on sodium hydroxide. Five different types of mixture were prepared, with filler/precursor ratios of 80/20, 60/40, 40/60, 20/80 and 0/100. All the specimens were cured at 80ºC for 7 days, after which they were submitted to a uniaxial compression strength (UCS) test. Three different values of curing humidity were considered, namely 25%, 50% and 75%. Each UCS value was the average of 9 different specimens tested. The aim of the present research is to establish how much these two factors (inert/precursor ratio and curing humidity) influence the UCS. For that purpose, a two-way Analysis of Variance (ANOVA), with interaction, was performed; followed by a Tuckey's Post Hoc test. The results showed statistically significant differences for at least one humidity value – $F(2,127) = 31.647$ ($p<0.001$) – as well as one inert/precursor ratio – $F(4,127) = 371.64$; ($p<0.001$) and for interaction $F(8,127) = 9.33$; ($p<0.001$). The Tuckey's post hoc test revealed that the humidity value of 50% presented statistically significant differences regarding the remaining two values. In addition, it was concluded that this humidity value (50%) leads to lower binder's resistance. Concerning the inert/precursor ratio, the nonsignificant differences only occur between the 80/20 and 60/40 cases, although the strength values increase, in general, as the ash percentage increases.

#256 Fatigue damage prediction of short edge crack under various load: Direct Optimized Probabilistic Calculation

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Abstract Fatigue crack propagation depends on a number and value of stress range cycles. This is a time factor in the course of reliability for the entire designed service life. Three sizes are important for the characteristics of the propagation of fatigue cracks - initial size, detectable size and acceptable size. The theoretical model of a fatigue crack progression can be based on a linear elastic fracture mechanics (uses Paris-Erdogan law). Depending on location of an initial crack, the crack may propagate in structural element (e.g. from the edge or from the surface under various load) that could be described by calibration functions. When determining the required degree of reliability, it is possible to specify the time of the first inspection of the construction which will focus on the fatigue damage. Using a conditional probability and Bayesian approach, times for subsequent inspections can be determined based on the results of the previous inspection. For probabilistic modelling of a fatigue crack progression was used the original and a new probabilistic method - the Direct Optimized Probabilistic Calculation ("DOProC"), which uses a purely numerical approach without any simulation techniques or approximation approach based on optimized numerical integration. Compared to conventional simulation techniques is characterized by greater accuracy and efficiency of the computation.

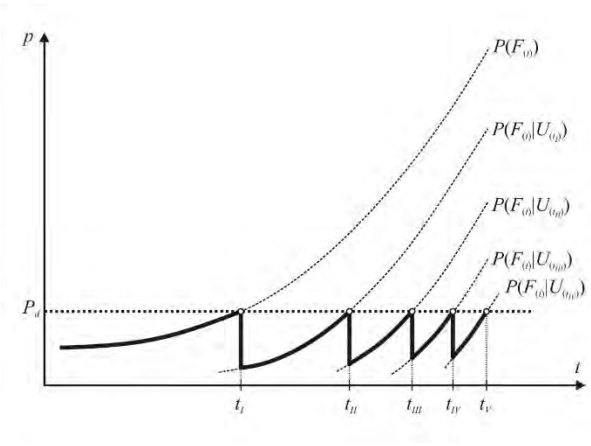

Figure 1 – *Design of structural inspections based on probability of failure P_f, conditional probability and required degree of reliability P_d*

#257 Restoration mortars for the Volubilis calcarenite stone

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Abstract Volubilis is the most important archaeological site in Morocco. It is located about 30 km from Meknes. It was a Mauritanian capital founded in the 3rd century B.C. and became an important outpost of the Roman Empire in 40 AD. Most of its monuments were built using a calcarenite limestone. The site was excavated in the early 20th century and has been registered on the UNESCO World Heritage list since December 1997. For preservation purposes, anamnesis and diagnosis studies were carried out and showed that there are many collapsed walls due to the low quality of mortars, composed of lime, mud and lime-mud as binder. Some recent grey mortars with high hardness were also observed. According to the conservation direction of the site, Portland cement was used to improve the strength of lime mortars. Previous analyses confirmed that these grey mortars and their neighboring deteriorated stones contain gypsum. This study was therefore performed to characterize the calcarenite stone and to propose a compatible mortar recipe for future interventions.

First blocks of calcarenite stone were collected from the original quarry and then cubic and cylindrical samples were made. Mortars were formulated using aerial lime and regional materials: brick dust and washed dolomitic sand. In order to study the effects of each compound, nine mortars were formulated (Table 1). Three lots of samples were prepared to be characterized after 1, 3 and 12 months of maturation. Physical and mechanical tests were carried out on calcarenite samples and one month mortar specimens: porosity (P), capillary absorption (A), color (L, a, b), P wave velocity (V), thermal conductivity (λ) and unconfined compressive strength (UC).

The results indicated that the calcarenite stone is a porous, soft and medium-absorbing stone (Table 1). Characterization of the mortars led to many important conclusions: brick dust decreases the porosity and the capillary absorption if used as lime substitution and increases them if used as aggregate. In addition, it improves compressive strength by a factor of two or even three and increases the P wave velocity. From a comparison of the calcarenite and mortars' properties, mortar M2 showed the best performances.

	Stone	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9
Lime (%)	-	10.0	10.0	10.0	25.0	25.0	25.0	40.0	40.0	40.0
Brick dust (%)	-	5.0	47.5	90.0	5.0	40.0	75.0	5.0	32.5	60.0
Sand (%)	-	85.0	42.5	0.0	70.0	35.0	0.0	55.0	27.5	0.0
P (%)	17	32	35	44	37	42	46	46	48	52
A ($kg/m^2h^{0.5}$)	2.03	3.08	9.79	11.95	5.76	15.09	13.85	11.28	20.71	15.59
UC (MPa)	18.45	1.14	3.40	3.69	0.86	1.83	3.20	0.45	0.95	1.33
V (m/s)	3101	1142	1442	1316	1027	1180	1133	917	1047	988

#260 Deformation monitoring of load-bearing reinforced concrete beams

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Abstract Cracking may occur in reinforced concrete building and engineering structures and their structural components under different service loads. The cracks in load-bearing elements (beams, supports) responsible for the integrity of an entire structure are of peculiar danger. The operation safety of these elements is currently assessed from the analysis of data obtained with the aid of deformation monitoring of structures.

This paper presents a version of the automatic deformation monitoring system (ADMS) deployed to monitor the reinforced structure, which is an air bridge connecting two parts of the building. The load-bearing elements of this bridge are the reinforced concrete beams bound together and resting on iron supports. During the service life of the bridge, crack formation is observed in the stretch zones in the beams.

The proposed automatic deformation monitoring system consists of the following main components: a system of primary sensors, a unit for transferring information from primary sensors to the central server, and a computer system for mathematical treatment and analysis, and for visualization of database and its presentation on website. The system of primary sensors is particularly interesting in that it allows one to register the process of local deformation in the vicinity of cracks and at the same time to control changes in the macroscopic parameters of the structure (vertical displacement of the transverse sections of the beam). Local deformations near the crack were measured by applying photogrammetry. The vertical displacement of beam elements was controlled by the hydrostatic method and the photogrammetry technique through measuring the displacements of the beam relative to a taut string.

The database obtained with this system of sensors is used as the initial information required for a mathematical model capable of describing deformation processes taking place in the entire structure and in all its parts. The ADMS computer system provides, on the basis of numerical modeling, information about the real deformation state of the structure and enables assessing its bearing capability. Thus, the system allows one to trace the evolution of the structure in going from its elastic state to cracking, which finally leads to the destruction of concrete elements and the breaking of armature. With this system, it is also possible to find crack localization zones corresponding to pre-critical and critical stages of structure and to estimate critical loads. The accumulated information about the deformation state of the structure makes it possible to predict the evolution of fracture processes and to estimate the period during which the operation safety of the structure can be assured.

So far, the proposed version of the ADMS has been used successfully on a real structure for 2 years. Analysis of the database obtained during its performance indicates seasonal changes in the crack opening width and a tendency for the crack opening to become wider with time.

#261 Effect of rivet holes on calibration curves for edge cracks under various loading type in steel bridge structure

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Abstract Attention to the fatigue cracks in steel structures and bridges has been paid for a long time. In spite of efforts to eliminate the creation and propagation of fatigue cracks throughout the designed service life, cracks are still revealed during inspections. There is some limitation of crack sizes, which are detectable on the structure (from 2 up 10 mm). Note, that depending on location of initial crack, the crack may dominantly propagate from the edge or from the surface. The theoretical model of fatigue crack progress is based on linear elastic fracture mechanics. Steel specimens are subjected to various load (tension, three- and four-point bending, pure bending etc.). The calibration functions for short edge cracks, that are near the hole for rivet or bolt, are compared for various load and the discrepancies are discussed.

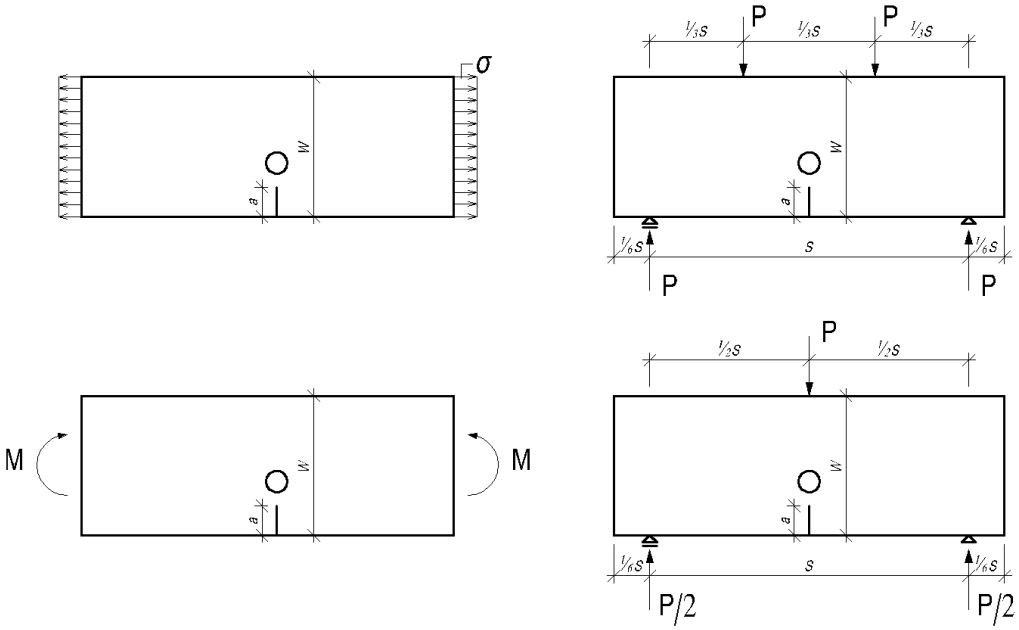

Figure 1 – Comparison of various loading type used in numerical models of bolted joint

#262 Corrosion effects on mechanical properties of sintered stainless steels

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Abstract Powder metallurgy process has numerous advantages to fabricate small pieces of complex shapes, because it allows energy and material savings as well as dimensional accuracy. Sintered stainless steels have a wide range of applications, mainly related to the automotive industry. However, they present lower properties than their wrought counter-parts in terms of corrosion and wear resistance. The main reason for this lower performance is the presence of porosity that could change the performance of material especially if exposed to corrosive environments. This paper studies the changes in mechanical properties of powder metallurgy 316L stainless steel sintered by selective laser melting subjected to corrosive atmosphere. Many different criteria for the evaluation of the test results may be applied to meet specific requirements. The aim of this work is to evaluate changing in terms of tensile properties, appearance after corrosion exposure, mass loss, changing in density and alteration revealed by micrographic examinations.

Three classes of sintered stainless steels have been analyzed. They differ, one from each other, for the laser power and for the speed scanning. For each class 9 specimens has been made up. For all of them both measurements of weight and density were carried out. One specimen of them was tested, *as received*, according to the tensile standard for metallic materials. Eight specimens for each class were placed in corrosive atmosphere in conducting the neutral salt spray (NSS) tests for assessment of the corrosion resistance of metallic materials.

Four different periods of exposure were defined, choosing among the recommended standard periods: 24 h, 96 h, 168 h and 240 h. A periodic visual examination of specimens under tests for a predetermined period has been made, but the surfaces under test has not be disturbed, and the period for which the cabinet is open was the minimum necessary to observe and record any visible changes. At the end of each test period, two specimens were removed from the cabinet. The test specimens removed were leaved at environmental conditions to allow them to dry for 0,5 h to 1 h before cleaning, in order to reduce the risk of removing corrosion products. Before they were examined, the residues of spray solution from their surfaces were carefully removed.

Visual observations, measurements of mass loss, density variations and tensile tests have carried out on all the specimens belonging to the specific exposure time, in order to evaluate and record all the changes referring to the specific conditions they were subjected.

#264 Failure mode analysis of a damaged diesel motor crankshaft

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Abstract. A crankshaft failure mode analysis of a diesel motor is presented. The aim of the study was to ivestigate the root cause of failure of this important mechanical component. This crankshaft belonged to a particular vehicle (116 HP, at 2800 rpm, 1950 cm^3) that after 125 000 km broke down. The crankpin nº 3 appeared fractured as well as the nº 3 main bearing cover. Samples were taken from the damage crankshaft for observing the microstructure of the steel, SEM analysis, and also to obtain the steel composition. Deffects of material and machining process were not found where the crack initiation tooke place. The failure mode clearly was by fatigue and the root cause seems to be related with the deficinte tightning of the main bearing cover which experienced a significant cyclic amplitude loading, before the crankshaft damage.

Keywords: crankshaft failures, alternating a rotating bending, mixed-mode fatigue.

***Figure 1** – Damaged crankshaft and the broken bearing cover nº3.*

#266 Crack growth from internal defects and related size effect in VHCF

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Abstract The research on the Very-High-Cycle Fatigue (VHCF) behavior of materials has recently gained significant attention, due to the increased fatigue life of components used in structural applications. According to the experimental results, internal defects play a major role in the nucleation of fatigue cracks in VHCF. In particular, fatigue crack in VHCF generally originates from small defects (inclusions, pores, voids) in the material. Unexpectedly, it has been found that crack can grow from the initial defect even if the Stress Intensity Factor (SIF) is quite below the characteristic threshold for crack growth. Even though researchers unanimously accept this singular experimental evidence, they still dispute about its physical justification. Different micromechanical explanations have been proposed in the literature: local grain refinement, carbide decohesion, matrix fragmentation, hydrogen embrittlement, numerous cyclic pressing and formation of persistent slip bands are the most famous proposals. Regardless of the specific micromechanical explanation, it is generally acknowledged that a weakening mechanism occurs around the initial defect, thus permitting the crack growth below the SIF threshold.

In the present paper an innovative approach for modeling crack growth from defects in the VHCF regime is proposed. An additional Stress Intensity Factor (SIF) that locally reduces the SIF threshold of the material is considered for modelling the crack growth from the initial defect. The proposed model is quite general and is in agreement with the different weakening mechanisms suggested in the literature. Moreover, from the proposed formulation, a general expression for the fatigue limit and a crack growth rate model for crack propagation from internal defect up to failure are defined. Starting from the well-known relationship between the defect size and the loaded volume of material (risk-volume), the fatigue limit as a function of the risk-volume is also defined. An illustrative numerical example, based on experimental data, is finally reported in the paper in order to show the applicability of the proposed model.

Keywords: Design and Structural Assessment, Fracture Analysis

#267 Finite element analysis of fretting contact under various pad geometries and materials

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Abstract Fretting problem arises in the case of relatively small sliding motion between contacting surfaces. This situation is observed in different kind of parts, such as bolted joints and lug attachments of aircraft and helicopters. Fatigue life of these parts may be significantly reduced due to fretting. The purpose of this study is to investigate the effects of fretting problem in the contact region in a cylindrical on flat contact configuration (Fig. 1a). In order to identify fretting phenomenon two different numerical models, which represent the fretting contact and fretting fatigue contact, are constructed by using commercial finite element package ABAQUS™. The contact between the pad and the specimen is described by utilizing master slave algorithm. Simulation of the Coulomb friction model is achieved by using Lagrange multiplier formulation for the tangential behavior and augmented Lagrange algorithm for the normal behavior. Effect of friction coefficient, pad radius and loading condition on the contact region are examined. In addition, in order to observe the real effect of the fretting phenomena on the bolted joints and lug type structures, effect of dissimilar materials in the contact region are also investigated. Numerically calculated stress results are compared with the analytical solutions. Classical Mindlin approach is used to model fretting contact and Nowell and Hills approach, which include the effect of the bulk stress in calculations, is used to model the fretting fatigue contact. The results are compared in terms of pressure, shear traction, tangential, von Mises stress magnitudes and relative slip between the contacting materials (Fig. 1b). In addition, stick/slip relations on the specimen surface of different configurations are investigated and compared with each other. For dissimilar materials, it is seen that Nowell and Hills approach gives a better agreement with FEA results.

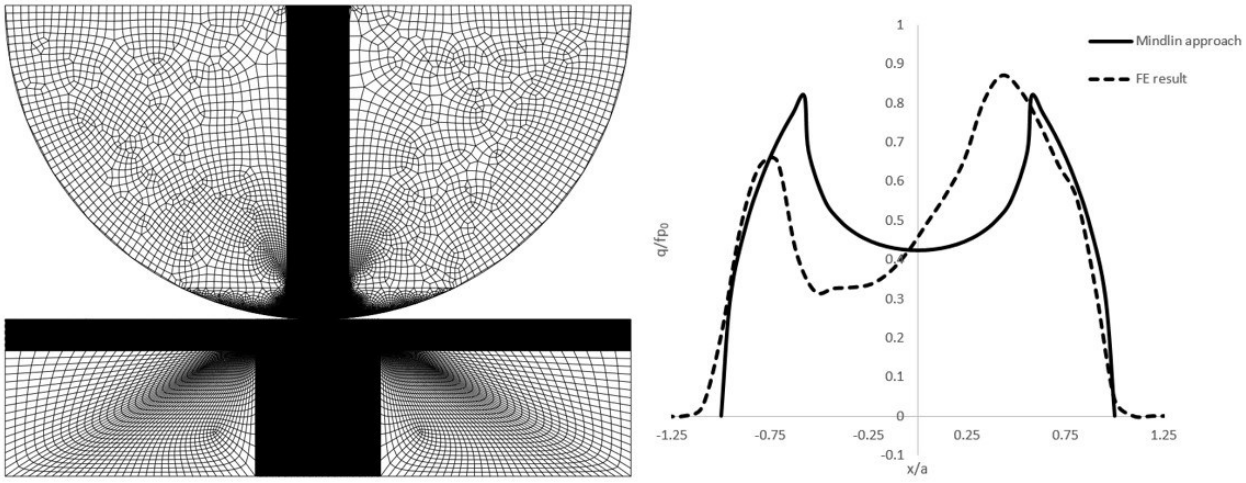

Figure 1- *(a) Finite element model of the cylindrical fretting contact, (b) Normalized shear traction distribution in the contact area for dissimilar materials.*

#268 Comparison of Equivalent Stress Methods with Critical Plane Approaches for Multiaxial High Cycle Fatigue Assessment

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Abstract Many critical engineering parts designed with safe life methodology such as rotor blades, pressure vessels, railroad wheels, crankshafts and bolted joints experience cyclic loading that leads to biaxial or triaxial stress states. Fatigue failure under such stress states is called multiaxial fatigue. Multiaxial fatigue is a complex problem due to multiaxial stress state, nonproportional loading and directional characteristics of materials and the fatigue process. Therefore, appropriate damage models should be used for accurate life estimations. In the present work, several equivalent stress methods and more advanced critical plane criteria are compared in terms of their performance in fatigue life estimations under uniaxial and biaxial loadings in which the effect of frequency, phase and mean stress is investigated. For this purpose a MATLAB code is written which transforms the multiaxial cyclic stress state into a uniaxial cyclic stress to use with the equivalent stress based method and Soderberg criteria for life prediction. An equivalent stress history based on the Signed von-Mises method for a nonproportional loading is illustrated in Figure 1(a). For critical plane approaches the program searches the maximum of a damage parameter on all material planes for the interval 0^o to 180^o for both angles (φ, θ) that define the normal of material planes. The maximum damage parameter is then compared with a material allowable obtained from uniaxial fatigue tests for life estimation. An example of a damage parameter distribution calculated according to the same loading history of Figure 1(a) is shown in Figure 1(b). In addition, various methods for calibration of the material coefficient k which adjusts the contribution of normal stresses and prominent stress history enclosure methods to calculate shear stress amplitude are also studied for improvements in critical plane approaches.

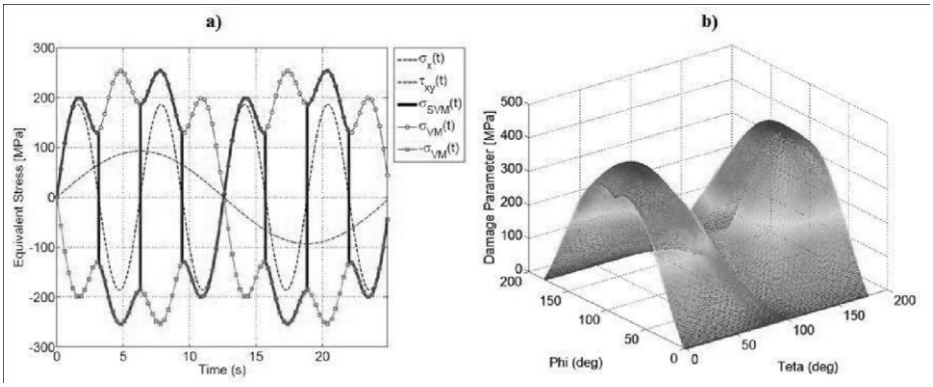

Figure 1: *(a) Equivalent stress history (b) Damage parameter distribution*

#269 Fatigue testing of axial and axial/torsion specimens at ultrasonic frequencies

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Abstract Fatigue damage has special relevance on the life span of mechanical components and structures, as it takes responsibility for the majority of the registered structural failures. Although its mechanisms have been the subject of continuous research, the growing need for greater lifespans forced the understanding of the behavior of materials under very high cycle loadings, also known as Giga Cycle Fatigue or more recently Very High Cycle Fatigue. On the other hand the behavior of materials under multiaxial fatigue has been the subject of research and development, but not in the region of very high cycles, due to the inexistence of appropriate machinery to perform these tests. The authors of this work have already a large experience on the performance of multiaxial fatigue tests under axial/torsion loading under servo-hydraulic fatigue testing machines and on very high cycle fatigue tests. In this context, and in order to understand the behavior of materials on the very high cycle region of the S-N curves and remarking the absence, for some materials, of the fatigue limit that used to be considered on mechanical design, a comparison must be carried out between the loading conditions determined in lower frequencies (servo-hydraulic testing) and very high frequencies (piezoelectric ultrasonic testing machines). In this paper, a device designed to produce axial and axial/torsional loading fatigue testing using a single piezoelectric axial exciter is briefly presented, as well as the instrumentation used on the preliminary testing of this device. The device is comprised of a horn and a specimen, which are both attached to the piezoelectric exciter. The steps taken towards the final geometry of the device, including special designed horn and specimen are presented. Experimental testing of the developed device is carried out using thermographic imaging, strain measurements and vibration speeds and indicates good behaviour of the tested specimen. Extensive experimental analyses were produced in order to qualitatively evaluate the dynamic behaviour of the device, specifically on the specimen. Laser vibrometer measurements have confirmed the correct axial and rotational behaviour of the free-end of the specimen. Thermographic imaging proved that maximum stresses are registered at the middle throat. A three-way rosette type strain gage was installed on the middle throat in order to acquire strains and evaluate the stresses present on this region, confirming the existence of a biaxial stress state. Results of stress and strain measurements on specimens tested under biaxial loading conditions, at static loading, lower frequencies and very high frequencies are discussed and analyzed. Results show that it is possible to carry out multiaxial (axial/torsion loading) fatigue tests at very high frequencies with comparable results with tests at lower frequencies which allow the development of faster and reliable very high cycle multiaxial fatigue tests.

#271 Polymer nanocomposites PE/PE-g-MA/EPDM/nanoZnO and TiO_2 dynamically crosslinked with sulfur and accelerators

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Abstract Nanocrosslinked elastic-plastic nanocomposites are blends that combine economically and performant properties of at least two polymers (elastomer and plastomer) and nanoparticles in a single product. In these blends the elastomeric phase is crosslinked in the thermoplastic melt blending under conditions of thermodynamic technology. This paper presents the development of multiphase elastic-plastic polymeric nanocomposites, dynamically crosslinked, reinforced with nanoparticles for products used in food and pharmaceutical domain, a new variety of composite material based on elastomer (ethylene-propylene-ter-polymer rubber - EPDM) and nanofiller (ZnO and TiO_2) dispersed in the plastomer matrix(high density polyethylene-HDPE). Elastomers and nanofiller by nanometric dispersion in plastomer matrix have led to obtaining a performant polymer material with multifunctional characteristics (rubber and thermoplastic) and processing properties specific to plastics. Also, the elastomer was dynamically cross-linked in the plastomer matrix, during processing, by classic vulcanization system with sulfur and accelerators. Accelerators used, namely tert-butyl-2-benzothiazyl sulphenamide -Vulkacit NZ and benzothiazyl-2-dicyclohexyl sulphenamide - Vulcacit DZ. The crosslinking method is ecological, without release of aromatic nitrosamines, which are carcinogenic in the crosslinking process. Obtained composites were physical-mechanical characterized by standard methods specific to plastics.

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#272 Polyamide/Polypropylene/graphene oxide nanocomposites with functional compatibilizers: Morpho-structural and physico-mechanical caracterization

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Abstract: Nanofilled polymeric matrices have demonstrated remarkable mechanical, electrical, and thermal properties. Compounding polymers with nanofiller is widely used for the preparation of new materials [1]. Polyamide/polypropylene (PA/PP) composites are interesting because both components are relatively cheap, with advantageous properties, and are processable by melt blending [2]. The compatibilisation of binary polymer compounds can be made by the addition of graft copolymer, segments of which have physical or chemical affinity with two immiscible homopolymers [3]. In this case, polypropylene grafted with maleic anhydride (PP-g-MA) it was used. Polymer nanocomposites containing graphite have been considered as a new generation of composites materials due to their expected unique properties attributed to the high aspect ratio of the inorganic pellets [4, 5, 6]. Combined effects of graphite treatment and compatibilizer polymers (PP-g-MA) on the structure and properties of PA/PP/PP-g-MA/graphene oxide composites were studies. The optimum formulation was used to prepare a series of nanocomposites under different technological conditions. The nanocomposites PA/PP/PP-g-MA/graphene oxide were characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), thermogravimetric and differential thermal analysis (TGA-DTA), Fourier transformation infrared spectrum (FT-IR) and physico-mechanical.

ACKNOWLEDGEMENTS

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#273 Measuring wood bending stiffness components by the virtual fields method: an integrated image-based approach

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Abstract The recent development of full-field optical techniques, have been enabling novel material parameter identification strategies. Contrasting with conventional test methods based on restrictive assumptions and performed on simple specimen geometries, this approach is based on heterogeneous and complex stress/strain fields generated over a gauge section allowing multi-parameter characterisation with suitable balance between accuracy and spatial resolution. This approach seems particularly convenient to wood and wood-based products.

The characterisation of orthotropic stiffness constants of Pinus pinaster Ait. is analysed based on a heterogeneous plate bending test. The proposed inverse identification approach couples full-field slope measurements provided by deflectometry with the Virtual Fields Method (VFM). A simulator tool was proposed to simulate the measuring and identification chain. Phase evaluation, phase unwrapping and numerical differentiation algorithms were applied to synthetic grid images, providing the reconstruction of the curvature fields over the plate. These kinematic field were then input into the VFM, together with applied load and plate dimensions, for material parameter identification assuming Kirchhoff-Love thin plate theory. The robustness of the approach is discussed and values compared with reference properties determined from classical mechanical tests.

#274 Efficiency of approximation methods for obtaining the strain fields from digital image correlation

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Abstract This paper presents an in-depth investigation on the effect of approximation methods on the accuracy of the obtained strain field from Digital Image Correlation (DIC) technique. DIC has been extensively used in the last years for monitoring the deformation of materials under mechanical tests. This technique is based on correlating the sequential images, taken from the specimens during the tests, to obtain the displacement fields using an image correlation algorithm. The full-field displacement fields are then converted to strain fields. Different local or global approximation methods can be used for conversion of the displacement fields to strain fields. A review of some of these methods and their accuracy in predicting the strain fields are presented and discussed in this paper.

#278 Intellectual monitoring of artificial ground freezing in the fluid-saturated rock mass

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One of the characteristic features of the modern underground building is an increase in the depth of deposits and, as a consequence, complication of geotechnical conditions. This circumstance is directly connected with the increase in the depth of the opening of unstable fluid-saturated rocks requiring special building methods. One of these methods is artificial ground freezing which is used for vertical shaft sinking. Effectiveness of this technique is confirmed by the long-term experience of its application in Russia and some other countries and is determined by the reliability of the ice wall with calculated thickness.

Modern development of artificial ground freezing technique is directly related to the increase in the depth of freezing. In turn, this is connected with economic efficiency issues and problems of guaranteed closure of individual ice bodies to a single wall as well as achieving the giving strength as soon as possible. Application of the developed in the 1990s recommendations and analytical techniques for the definition of freezing time, the required thickness of the ice wall, the diameter of the circle of the freezing columns location, their number lead to the two limiting cases: creation of non-tight ice wall or formation of ice wall with excessive thickness which is not effective from the economic point of view. One of the possible solutions of the problem is the development of monitoring system which includes both a numerical simulation module and spatial distributed monitoring system.

Solution to the problem of artificial ground freezing with the use of the direct numerical simulation depends on the two factors: initial data on the thermal and mechanical properties of rocks and adequacy of the used physical model.

This work consists of two parts. The theoretical part is devoted to the development of coupled thermo-hydro-mechanical model of fluid-saturated poroelastic media under an assumption of the full transition of liquid into ice. This model is used for numerical simulation of artificial ground freezing of one of the potassium salt deposits taking into account available geophysical and physical data. The additional attention was paid to the solution of an inverse problem to determine unknown physical properties of the soil and temperature distribution. The experimental part includes the development of real time temperature monitoring system. The temperature in the ground is measured using fiber-optic interrogator Silixa Ultima based on the Raman Effect. The fiber-optic system is located in several measuring boreholes and has a length of several hundred meters. The temperature is measurement with the step equals 025m. The temperature of the cooling brine in the freezing pipes is carried out using hardware-software complex Siemens.

To illustrate the efficiency of the developed system the examples of real monitoring of artificial ground freezing in the fluid-saturated rock mass and simulation of freezing and defrosting processes would be presented.

Acknowledgements

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#280 Fatigue lifetime improvement and possible fatigue crack growth retardation effect in AISI 304 stainless steel due to high-density electropulsing

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Abstract

The purpose of the study was to investigate the effect of the use of high density pulsed current (using supercapacitor) on the fatigue life of the tested specimens. For this purpose, experimental analyses were carried out for a two group of samples: without current pulsation and after current exposure. The results of the study for AISI 304 steel (0.04% C, 1.2% Mn, 18.16% Cr, 8% Ni, 0.335% Mo, 0.041% Si) for fatigue strength were presented. The experiments were performed on single edge notched tensile specimen (SENT) with U-shaped electro-drilling (W = 15mm, t = 0.5mm, a_0 = 2.5mm). Positive current pulses with different durations and frequencies were used. The tests were carried out on a hydraulic pulsator MTS 810, controlled by a constant force amplitude F_{max} = 1100N. DIC (Digital Image Correlation) method has been also involved for investigation the plastic radius length. The differences were also confirmed by SEM images of fatigue crack in to two states of material: before and after high-density electropulsing. Obtained initial results encourage for further analyzes and studies with a number of factors that allow the use of high current electricity in the context of increasing the fatigue life of tools or products obtained by plastic metal forming.

#281 Inhalation of Fumes in Rehabilitation, Civil Construction and Public Works

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Abstract Increasingly, buildings and structures are rebuilt, notably in the historic downtown area, as well as manors, farms, forts, castles, palaces and other buildings, some of which fall under the criterion of historical monuments, municipal, national or even world heritage .

The techniques and materials used in the old construction, the sometimes uneven plant, difficulties in ventilation and internal circulation, lead to the need to remove materials, for example by using heat and/or fire.

Heat and flame acting on such materials, for example asbestos coatings, old plastics or bakelite materials, lead-based paint, painted or lead-painted pipes, may release toxic and/or carcinogenic gases and vapors.

It is necessary to know the reality of the situation, through a careful inspection, to try to avoid short-term and/or long-term consequences for the workers in action and even for the owner, inspections and visitors, also in some cases, for visitors from other floors.

At the entrance to the work site, there must be perfectly identifiable zones which present specific risks and what preventive measures and protection equipment are required. The air circulation zones and their appropriate minimum speed must be indicated and monitored.

In small structures usually there will be no more than 2 to 3 workers per division, but in the recovery of large constructions, with numerous floors, the structure can be recovered floor by floor, there being one or more floors in recovery, but still others in activity, with tens or even hundreds of users, as in the case of shopping centers, hotels, hospitals.

In the event of fire or thermal pickling techniques, short circuits, gas cylinder deflagration or even terrorist attacks, the connections between floors, either by the columns of the elevators or by the staircase, can bring to the other floors toxic products.

The aid must be organized taking into account the characteristics of the works, taking into account the hypothesis of the production of carbon monoxide or, for example, cyanides.

#282 Control, Measurement and Monitoring Plans with Risk Assessment Application to Rehabilitation works

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Abstract

The sector of the rehabilitation of buildings is developed in a growing context and of great demand in the rigor and ability in the management of production is a necessary condition for providing the best service and product to the customer, being an essential condition for maximizing profitability of construction activities.

Defects and reworks should not be accepted as inevitable or even as certainties, but considered as a permanent challenge to the management of the work, being important to use risk assessment techniques in the planning and control of operations.

The purpose of this article is to present a methodology for the elaboration of Control, Measurement and Monitoring Plans, within the framework of the production processes of a rehabilitation work, where it is necessary to ensure compliance with technical and regulatory requirements, based on the thinking on the associated risks.

It is argued that this methodology has application and can contribute in reducing the variability and uncertainty of defects and reworks associated with the production of building rehabilitation works.

Keywords: Control, Measurement and Monitoring Plans*, Analysis and Risk Assessment, Building Rehabilitation Works*

#283 A numerical investigation of stress intensity factor for bended chevron notched specimens: Comparison of 2D and 3D solution

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Abstract In the contribution, normalised stress intensity factors for three- and four-point bending specimen with the chevron notch are calculated for varying chevron notch angle and the initial length a_0. This parametric study will lead to formation of calibration curves for each configuration. The three- and two-dimensional models of bended chevron notched specimens in software ANSYS were prepared with using of possible conditions of symmetry. The 2D model was prepared with help of variable thicknesses of the layers representing the characteristic shape of the chevron notch (with plane stress condition). The numerically obtained results from 2D and 3D solutions are applied to calculation of fracture toughness and compared to experimental data from literature measured on Al 7075.

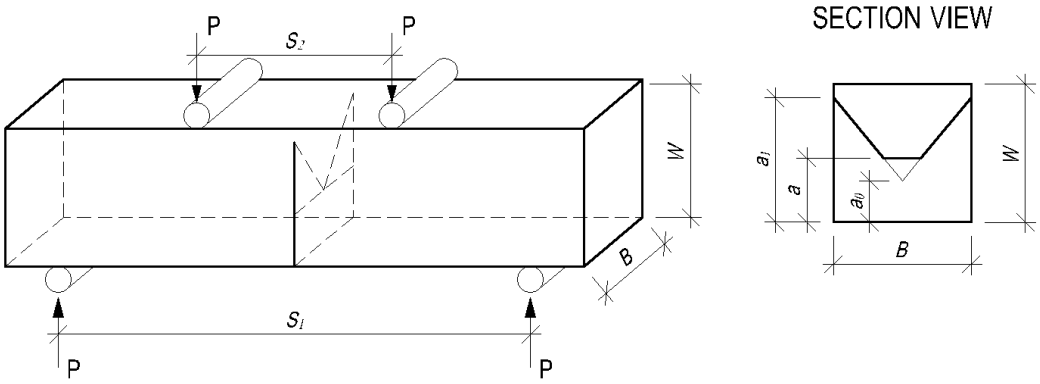

Figure 1 – Schematic of four-point bending specimen and description of the chevron notch

Acknowledgement The authors acknowledge the support of Czech Sciences foundation project No. 17-01589S.

#285 Chemical and morphological analysis of dust from rehabilitation works at Parque das Cardosas - Porto

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Abstract Nowadays, cities historic centers desertification has been assumed as one of the greatest problems of urbanism and territorial planning**.** This trend is due to the better offer of life quality, housing with better conditions and more competitive costs, proximity to work places and mobility problems found in the in the surroundings. Thus, the urban centers became depopulated, degraded and present health, social and security problems.

This study consists on the evaluation and characterization, of the content and type, of particles and nanoparticles, potentially existing in urban rehabilitation works. The samples were collected in a rehabilitated building, in the Parque das Cardosas, Oporto downtown. The first collection was done before rehabilitation began and the second and last one, after completing the work.

Powder samples were morphologically and chemically analyzed in order to determine the type, form and composition of the present particles. For the chemical and morphological characterization, Scanning Electron Microscopy (SEM), X-ray Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD) techniques were used.

It was concluded that, from the demolition phase to the rehabilitation phase, new chemical elements such as P, Cl, Al, Na and Ti appeared, and some the initial elements such as, Si, Ca, Mg, S, K, Fe and Al were maintained. There was an element that was eliminated in the process, Zn.

Using XRD analysis, from the demolition phase to the rehabilitation phase, there were significant modifications, namely the disappearance of compounds such as Biotite and Muscovite and the appearance of new components, such as Gypsum.

#286 Specificity of roofing rehabilitation with asbestos

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Abstract Asbestos is a mineral, of natural origin, made up of fibers, that due to its outstanding properties was used at a large scale in a variety of industrial sectors until the end of the 20th century**.** Asbestos is estimated to be present in more than 3,000 products, which means that it is found in most of the buildings built by the end of the 1990s. This material has excellent physical and chemical properties, which ensure excellent behavior, such as: high temperature and acid resistance, good thermal and acoustic insulation, as well as good chemical stability and low cost. However, there were no suspicions of its negative effects on public health, which may often take years to manifest in the human body.

With the purpose of studying the problem of buildings where asbestos is present, a bibliographical research was done on these fibers, in terms of health and safety. Since this material was frequently used in coverings, during the 40's and 50's, a case study of this type was chosen for experimental studies.

Specific tests were carried out with the purpose of characterizing and identifying the type of asbestos fibbers present in the samples obtained at the study site. Subsequently, the concentration of suspended fibers in the atmosphere was verified, during and after, the rehabilitation work activities.

With regard to the rehabilitation of buildings with asbestos in Portugal, it is mandatory to prepare a file of procedures, in accordance with the provisions of Decree-Law No. 266/2007 of July 24, since there are increased risks for workers evolved. Using the electronic microprobe and the bench electron microscope, it was possible to identify the type of fibber present in the samples.

#288 Multisite Fatigue Cracks Evaluation in Riveted Joints with Acoustic Emission Approximate Entropy Approach

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Abstract Most of the structural joints in metallic airframe are fabricated with riveted joints. Formation of fatigue cracks in riveted joints during the service usage are very often encountered in aircraft industry. Wide spread fatigue damage, multi-site damages are consequence of initiation of clusters of fatigue cracks in riveted joints and threat in the structural integrity. Detection and understanding the initiation and growth behavior of fatigue cracks in riveted joints is extremely important to maintain the structural integrity of the airframe as well as for aging aircraft operating in extended life. The experimental research work projected here is carried out to understand the multisite fatigue crack behavior in riveted joints that are commonly employed in metallic airframes with approximate entropy on acoustic emission signal parameters.

Experiments were done on riveted single strap butt joint specimens fabricated with aluminium AA 2024 material that is widely used in airframe construction. Specimens are fabricated with different configurations such as without cracks, with induced crack, with multiple cracks etc around the critical stress regions of the joint. Extraneous acoustic noise generated from riveted joints such as due to fretting, rubbing of surfaces etc. during fatigue loading will make the conventional way of acoustic emission signal analysis a difficult task to obtain any useful inference on fatigue cracks.

Quantification of complexity in various parameters such as hits, count, amplitude, spectral features of acoustic emission signals acquired from the fatigue loading are analysed with approximate entropy approach to understand crack growth behavior. The specimens have been subjected to constant amplitude fatigue loading in long span computer controlled universal testing machine. The fatigue load cycles were discretized as peak, transient and trough that are then attributed to AE parameters for quantifying. Increasing, decreasing trends, rate, slope and oscillating approximate entropy magnitudes are related to the crack growth behavior. Evaluation is focused on discriminating various stages of fatigue cracks such as crack initiation, stable crack growth, accelerated crack growth, coalescence of cracks etc. Results shows the approach followed here on detection capabilities and discrimination of stages of crack propagation can be very good candidate for evaluation fatigue cracks in riveted joints.

#290 Experimental fatigue tests of resin-injected and standard single bolted connections combining S355 mild steel and old material from Eiffel Bridge

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Abstract Among the different strategies that can be implemented in the repairing and strengthening operations of old riveted steel bridges, resin-injected bolts have been used to replace faulty rivets and preserve the slip resistance of the joint. This technology is preferred since it only requires a standard preparation of the holes and its structural performance depends not only on the friction behavior between steel plates. However, resin-injected bolted joints have been essentially tested for its quasi-static or creep behavior and very few studies concerned the assessment of its fatigue resistance. This paper presents the results of an experimental program aiming the evaluation of the fatigue behavior of resin-injected single shear bolted joints comparing to standard single shear bolted joints. Specimens are composed of new steel (S355 mild steel) and old steel plates obtained from structural elements of Eiffel bridge. With this specimen's configuration is intended to reproduce as close as possible the real situation of strengthening techniques. Fatigue experimental data are compared to fatigue design curves proposed in Eurocode 3, part 1-9.

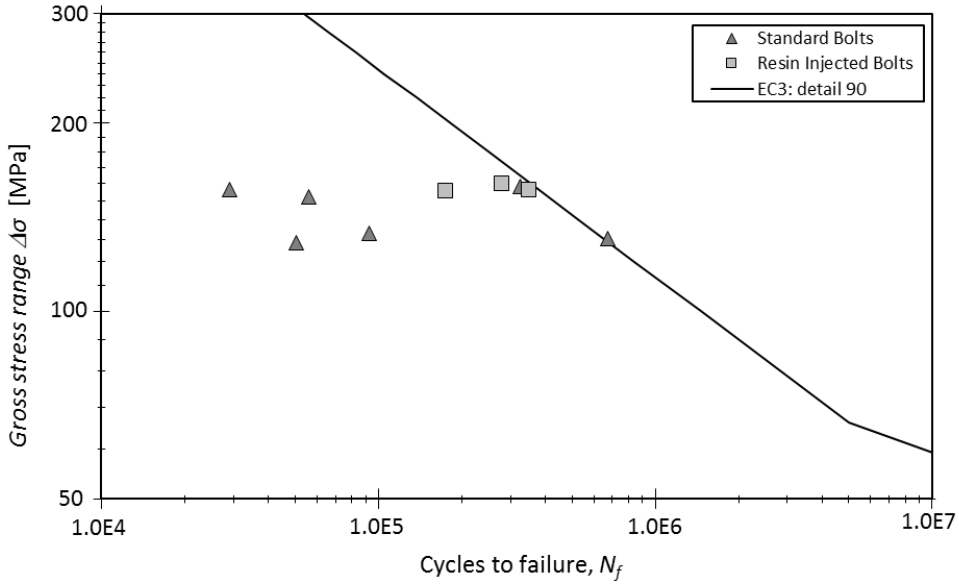

***Figure 1** – Fatigue experimental results of single shear bolted connections*

#291 Evolution of a fracture mechanism in a polymeric composite subjected to fatigue with the self-heating effect

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Abstract Fatigue fracture processes occurring in polymeric composites are different than those observed for metallic structures due to occurrence of a self-heating effect, i.e. a phenomenon resulting from viscoelastic mechanical energy dissipation and heat generation in the cyclically loaded structure. The self-heating effect, which may occur in stationary or non-stationary regimes, always influences on the fatigue process and residual life of a structure. In case of the stationary self-heating, when the generated heat is in equilibrium with thermal energy released to the environment, the fatigue life decreases, but without significant acceleration. In contrast to this case, during the non-stationary self-heating, fatigue fracture is significantly accelerated and leads to failure in a very short time period. Therefore, it is essential to investigate a criticality of the self-heating effect in a context of a self-heating temperature generated inside a structure at which damage is initiated as well as a character of development of a fracture mechanism and its development with respect to growing self-heating temperature. This allows for better understanding of physics of fatigue fracture in polymeric composites subjected to self-heating.

In order to reflect degradation processes and their evolution at various values of a self-heating temperature with a possibility of analyzing an internal structure of cracks and delaminations occurring during fatigue, the X-ray computed tomography tests were performed. Specimens made of a GFRP composite were subjected to cyclic loading in order to stimulate the non-stationary self-heating of the structure. The loading was stopped when a certain assumed self-heating temperature value on a surface of a specimen was reached. The observations were performed in a temperature range starting from 35°C and ending at 115°C, when the total failure was observed. A temperature step was of 5°C.

The performed tests allow for characterization of morphology of damage occurring during fatigue loading of polymeric composites subjected to dominated self-heating, and, based on the performed observations, determination of a critical self-heating temperature value, which causes appearance of internal fracture in a structure. Moreover, a continuous acquisition of a self-heating temperature and acoustic emission during fatigue allows for connection of fracture events with particular events observed in temperature and acoustic emission signals, which, in turn, allows for better understanding of formation of fracture in a structure in such loading conditions.

#293 Fatigue crack propagation analysis of bridge details by parallel computation of modal stress intensity factors

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Abstract Global-local integrated fatigue crack propagation analysis of bridge details was computationally improved by the so-called concept of modal stress intensity factors and the modal superposition method [Albuquerque et al., International Journal of Fatigue, 81, 61-77 (2015)], providing a powerful tool for fatigue assessment of critical details. However, for large structures such as bridges, a significant number of vibration modes are usually needed to obtain accurate results, increasing the calculation time. In the current paper, the referred methodology is modified to allow the automatic parallel computation of all the relevant modal stress intensity factors. The modified workflow is applied in the framework of the fatigue assessment of a railway bridge detail. It is demonstrated that the adapted procedure can achieve shorter computation times through parallel processing.

#294 Development of an efficient approach for fatigue analysis of bridge critical details using modal superposition of stress intensity factors

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Abstract The fatigue damage assessment in existing large engineering structures is highly conditioned by the computationally demands of global models and detailed local models that are needed to a proper structural analysis. The dynamic analysis of the problem using direct integration methods is impracticable in most of the cases, which leads to the necessity of development of the modal superposition method in order to increase the efficiency and allow more accurate structural analysis of the fatigue crack propagation problem.

Albuquerque et al. [International Journal of Fatigue, 81, 61-77 (2015)] proposed an effective workflow applicable to the present issue. The aim of this paper is to develop such methodology for the fatigue assessment of bridge details, using Fracture Mechanics and crack propagation laws. The mentioned workflow considers the combination between global and local refined numerical models, more specifically the use of submodelling techniques shell to solid, and the application of modal superposition method with the concept of modal stress intensity factor. The fatigue assessment process is applied to a complex welded critical detail of a recent railway bowstring bridge located in Portugal.

#301 Cable-stayed SNP Bridge in Bratislava

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[2]*Assoc. Professor, Department of Structural Mechanics, Faculty of Civil Engineering, STU, Radlinského 11, 810 05 Bratislava, Slovak Republic, yvona.kolekova@stuba.sk*

Abstract The bridge was designed by teams from Slovak University of Technology (STU former SVŠT) in Bratislava led by Professors Arpád Tesár (structural engineer), Ján Lacko (architect) and Associate Professor Jozef Zvara (structural engineer). Prof. Tesár graduated at TH Berlin – Charlottenburg in 1944. Prof. Lacko graduated at German Technical High School (Deutsche Technische Hoschschule) in Prague in 1941. Assoc. Prof. Jozef Zvara graduated at STU in Bratislava in 1952. All three were teachers at STU. Tesár`s team from Department of Metal and Timber Structures consisted of: E. Chladný, P. Dutko, V. Voříšek, J. Schun, J. Virčík, Z. Agócs, J. Lapos, J. Vajda, P. Ferjenčík, I. Plašil, E. Chomová, Z. Illetšková, F. Draškovič, K. Amon. Lacko`s team was created by architects L. Kušnír and I. Slameň. Zvara`s team from Department of Concrete Structures and Bridges consisted of: Š. Baďura, F. Brtáň, F. Hájek, E. Holub, Š. Choma, D. Majdúch, E. Madunický, J. Krajňák. Team from Department of Surveying: O. Michalčák, J. Staněk, D. Píš, F. Kohút, P. Bartoš and from Department of Structural Mechanics V. Složka were another people who took part in design of SNP Bridge. Fig. 1 shows photographs of 3 team leaders and 3 members of Tesár`s team.

Figure 1 *– Left:Prof. Dr. Ing. Arpád Tesár, DrSc. (*1.II.1919 - †15.VI.1989), Prof. Ing. arch. Ján Lacko, CSc. (*19.1.1917 - †9.IX.1978), Assoc. Prof. Ing. Jozef Zvara (*17.VII.1925 - †29.II.2004), Prof. Ing. Eugen Chladný, CSc. (*1.VIII.1928), Prof. Ing. Pavol Dutko, CSc. (*23.X.1928 - †29.III.1928), Assoc. Prof. Ing. Vladimír Voříšek, CSc. (*9.VI.1924)*

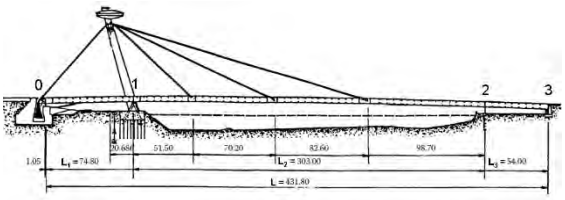

Figure 2 – S*NP Bridge over Danube river in Bratislava, 1972 with main span 303 m*

Description of the SNP Bridge, imperfection measurements, inspection, load-carrying capacity evaluation, comparison of theoretical results and loading tests, strengthening and comparison with the current world record main span holders in category of cable-stayed bridges are given in the main paper.

#304 Estimation of microstructural failure probability based on restoration of the field distributions laws in components of heterogenous media

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Abstract One of the common approaches in the micromechanics of structurally inhomogeneous media with a random structure is connected with the methods of statistical mechanics. Deformation and fracture processes in structurally heterogeneous materials depend on the peculiarities of local stress fields, for calculation of which fluctuations and deviations from the averaged values, caused by inhomogeneities at the microscale, are important. A common direction in micromechanics of materials with random structure is studying many-particle systems when multi-point statistics for stresses, deformations and displacement fields are used to describe the interaction of inhomogeneities. The characteristics of the fields presented in this way allow taking into account randomness of elements arrangements in the structure, as well as dispersion of the properties of the components.

The approach to the analysis of the distribution of stress and strain fields in representative volumes of heterogeneous media introduced in this work is based on reconstruction of the distribution laws for each component. Heterogeneity of the microstructure has a significant effect on the distribution of stress and strain fields in representative volume elements. Methods and tools of statistical analysis make it possible to investigate these distributions from the analytical point of view. In this case, for example, the characteristics of failure of representative volume and its components can be expressed in probabilistic quantities. The approach presented in this work allows to investigate probability of fracture initiation for the RVE phases basing on statistical representation of fracture criteria and recovery of the stress and strain distribution functions in phases. In general case, such statistical approach can be used for investigation of the influence of spread of the microstructure parameters as well as the constants of an inhomogeneous medium on the strength characteristics of the material.

Methods for finding parameters of distribution laws are described, different types of distribution laws were compared. The technique of analysis of failure probability of microstructural elements is given. Some numerical results for particular case studies are presented. Implementation of the methodology was performed using finite element analysis based on a mesh with voxel-type elements.

#305 Numerical study on damage identification using shearography with different shearing amounts

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Abstract Shearography is a technique appropriate for the analysis of damage, namely by allowing the direct measurement of the gradient or derivative of the displacement field, i.e. the rotation field. The measurement sensitivity can be adjusted by varying the shearing amount, such that we obtain large sensitivities with high values of this parameter. However, high values of shearing amount lead to the smoothing of the results. The aim of this paper is to report a study on damage identification using shearography with different shearing amounts. The main objective of the study is the establishment of a range of shearing amounts that can lead to correct localizations of structural damage in beams using modal response. A free-free aluminum beam is discretized by finite elements and the modes shapes, i.e. the modal displacement and rotation fields, are obtained in both undamaged and damaged states. Modal curvature fields obtained directly from the finite element analysis and obtained by simulating shearography are used to compute damage indicators. The damage indicators computed using the data from the simulation of shearography show a great dependency on the shearing amount, as shown in Figure 1. In fact, for large shearing amounts, it seems that the damage is spread across a larger area than the actual one. Also, the peak values of the damage indicators present an attenuation and the damage area also increases with the shearing amount. Thus, it is advisable to take these findings into consideration whenever we analyze results coming from shearography with the objective of localizing damage.

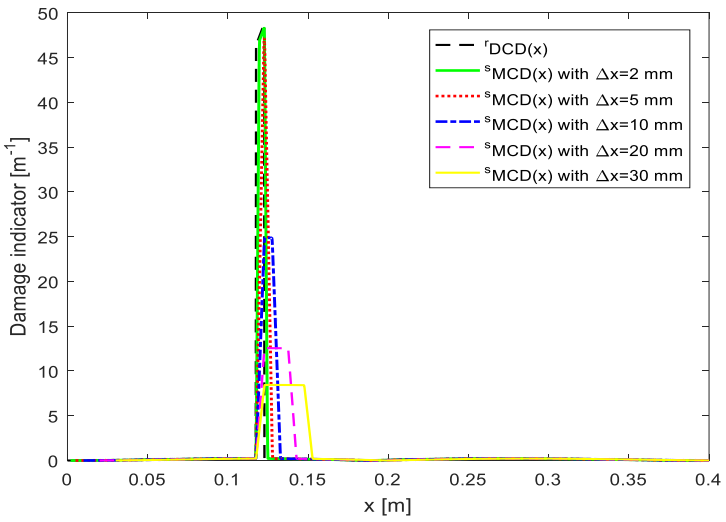

Figure 1 - *Damage indicators for a reduction in the bending stiffness (EI) of 10%.*

#306 Influence of shearing amount and vibration amplitude on noise in shearography

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Abstract A method for the evaluation of noise in measurements with shearography is reported in this paper. The evaluation of noise in measurements with shearography is one of the most important steps in finding its accuracy. However, a detailed analysis of noise in shearography has not been reported yet, mainly because for its evaluation it is necessary to know the continuous full-fields, which are obtained from the discontinuous measured phase maps. Thus, the procedure to quantify the noise is not straightforward, since it is necessary to resolve simultaneously the phase discontinuities and the ambiguities in the phase maps. A recent method has been proposed to overcome these problems and is applied here. A flowchart describing the main steps of this method is shown in Figure 1.

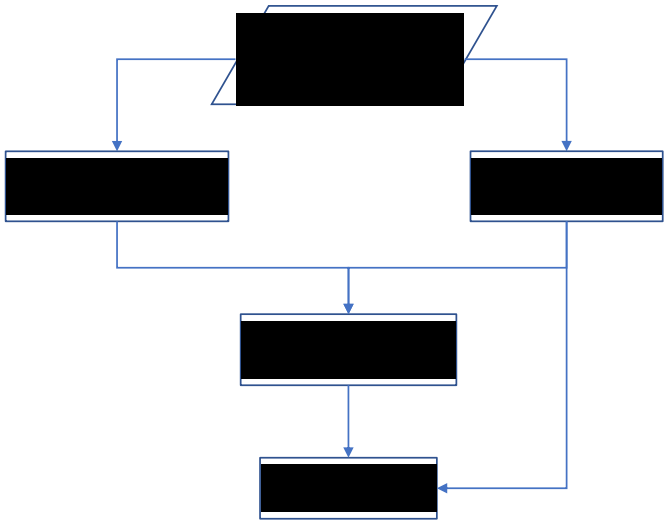

Figure 1 - *Flowchart describing the method for the evaluation of noise.*

The present paper reports the analysis of noise on experimental measurements produced by several setup parameters. With this purpose in mind, the first four modal rotation fields of a free-free beam were measured using a digital shearography technique. Two sets of measurements were carried out to investigate the influence of the shearing amount and the vibration amplitude of rotations on the noise. The results show that the best measurements are obtained for the first modal rotation field with the largest values of the shearing amount and maximum vibration amplitude.

#307 High cycle fatigue properties of explosively welded laminate AA2519/AA1050/Ti6Al4V

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Abstract The paper presents preliminary results of high cycle fatigue properties, including fatigue cracking of layered laminate AA2519/AA1050/Ti6Al4V. The test material was obtained by the method of explosive bonding in direct configuration AA2519/Ti6Al4V with the intermediate layer using a AA1050 alloy. The study tested influence of the applied heat treatment on the mechanical properties of the laminate. Loading applied during the tests was oscillating sinusoidal with the stress ratio R=0.1 and constant load frequency equal to 20 Hz. The tests were performed at five levels of stress amplitude dependent from shape of samples. Assumed as the criterion for the end was the number of cycles at specimen failure or when number of cycles was equal to 5 million repeats. The results indicated the beneficial effect of the applied heat treatment. The results showed an increase the fatigue of the heat-treated samples, both notched and smooth samples. For samples with a hole increase in fatigue life were observed only in the tests above σ_{max}=150 MPa. The biggest, 30-percent increase in the durability of these samples occurred during testing at σmax=250 MPa. The analysis of samples of smooth heat-treated samples showed an increase in stability after a heat treatment of 20-30% in the range σ_{max}=175-350 MPa. The results of electron microscopy studies of surface fatigue fracture allowed to determine the location of sources of fatigue cracking, which in the case of samples without heat treatment were in the area of border merger Ti6Al4V-AA1050. Sources of cracking in the elements after the heat treatment were located within the edge of the samples.

#308 Crack Growth Rate Curves of Hydrogen Embrittled Steels. Fatigue Frequency and Concentration Influence

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Abstract. There is an upward trend in the use of clean energy which has produced a rise related to design and manufacture of fuel cells and hydrogen filling stations under high hydrogen internal pressure. Many of them are made of steel. The hard work conditions of material can originate embrittlement by hydrogen because of the entrance of this element in the atomic structure of steel.

The hydrogen is present in several situations where it is necessary to take into account the effects that can be produced related with corrosion processes and the application of cathodic protection in engineering.

This work presents an experimental study which analyses the influence of hydrogen presence on the crack growth rate curves. A medium and high strength steels have been studied. All specimens have been charged with hydrogen before testing. A hydrogen analyser device has been used to measure the diffusivity in each material. The analysis in the evolution of FCG curves is developed based on hydrogen concentration and the frequency on the fatigue load applied in the tests. The influence of the test frequency has been analysed.

#309 Contribution of Maintenance Effectiveness in built heritage interventions

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Theme: Compatibility studies for preservation and restoration procedures and monitoring of interventions effectiveness

There´s growing awareness about the importance of preserving the legacy assets of cities and also, a need for built heritage protection of premature aging. In reality, this achievement is only possible with the implementation of preservation and maintenance mechanisms for buildings with heritage value, with particularly relevance in the context of restoration interventions. However, interventions and results expected demonstrate that after the interventions, may not be ensured the appropriate functional performance levels.

The present study sought analyze and develop maintenance contents, by defining a set of maintenance policies attributes to preventive maintenance strategies, with an additional contribution, since it includes the presumption of Maintenance Effectiveness. This paper aims to originally propose an approach methodology to approval the relation between the objective of maintaining and the result obtained, which is the aim of Maintenance Effectiveness.

The proposed methodology estimates the Maintenance Effectiveness through the development of contents based on a correlation matrix which corresponds to the ratio between performance conditions and the severity criteria (mode of use and type of exposure) and between the occuppant´s attitude under maintenance conditions and the use priority criteria (Undemanding, Moderately challenging, Very challenging) assessing the needs of maintenance policies for the various Maintenance Source Element – MSE.

Results generically proved the method as a valuable tool, endorsed through a case study whose correlation matrix is applied to a building with heritage value, and whose maintenance contents allowed define a systematic evaluation of information for Maintenance Effectiveness patterns, being applied to the MSE – External Windows.

Keywords: Heritage value, Building Maintenance, Maintenance Effectiveness, Performance conditions, Severity criteria, Maintenance conditions, Use priority criteria.

#310 Hydrogen Transport to Fracture Sites in Metals and Alloys: Multiphysics Modelling

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Abstract Generalised continuum model of hydrogen transport to fracture loci is developed for the purposes of analysis of the hydrogenous environment assisted fracture (HEAF). The model combines the notions of the theories of gas flow, surface science, and diffusion and trapping in stressed solids. Derived flux and balance equations describe the species migration across different states (gas, adsorbed specie at the gas-metal interface, interstitial solute in metal bulk) and a variety of corresponding sites of energy minimums along the potential relief for hydrogen in a system. The model accounts for the local kinetics of hydrogen interchange between the closest dissimilar neighbour sites and for the nonlocal interaction of hydrogen trapping in definite positions with the species wandering in their farer surroundings. In particular situations, certain balance equations of the model may degenerate into equilibrium constraints, as well as some terms in the generalised equations may be insignificant. A series of known theories of hydrogen transport in material-environment system can be recovered then as particular limit cases of the generalised model. Presented theory can help clarifying the advantages and limitations of particularised models so that appropriate one may be chosen for the analysis of a particular HEAF case.

#311 Paris Law-Based Approach to Fatigue Crack Growth in Notched Plates under Tension Loading

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Abstract Paris law approaches to fatigue crack growth in notched plates are based on the stress intensity factor (SIF). In this paper the crack path is studied for corner and surface flaws emanating from semicircular notch in plates of finite thickness subjected to cyclic tension loading. To this end, a numerical modeling was performed to evaluate the advance of the crack front on the basis of the Paris equation and the stress intensity factor solutions provided by Newman et al. Results show how the growing cracks tend towards a preferential propagation path. The convergence (closeness between crack propagation curves) is faster as the ratio of the notch radius to the plate thickness increases, and also quicker for corner cracks tan for surface flaws.

Keywords: Corner crack; Surface crack; Plate with a semi-circular notch; Fatigue crack propagation; Preferential propagation path

#312 Displacement measurement and shape acquisition of an RC helicopter blade using Digital Image Correlation

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Abstract The present work addresses the development and implementation of an image sensing methodology for Structural Integrity Monitoring of rotating parts such as aircraft rotor blades. The availability of blade deformation data can enhance the quality of the numerical models and increase the confidence on the simulations. The proposed approach to the problem of deformation measurement on moving subjects uses simultaneously triggered high-speed cameras to bring the rotating subject to an apparent still position, and using 3D Digital Image Correlation (DIC) thereafter to acquire shape and measure total deformation and local strain and stress. The presented contribution involves the use of 3D DIC for displacement measurement and shape acquisition of a radio-controlled helicopter's rotor blade under dynamic loads resultant from rotation at its minimum and maximum speeds (approximately 600 and 1200 rpm respectively).

#313 Currently used systems of dental posts for endodontic treatment

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Abstract An advanced stage of a tooth decay promotes an extremely damaged tooth that needs endodontic treatment to be restored. When satisfactory coronal tooth structure remains, an artificial crown can be placed without a post. On the other hand, the treatment of seriously damaged teeth often require an endodontic post. The main reason for using post is to enable rebuilding of the tooth structure prior to crown restoration. Dentists believe that endodontic posts provide a stable and solid restoration of the tooth, as well as providing strengthening of the tooth root, which constitutes the solid basis for a dental crown restoration. However, some authors reported that the strength of the tooth is directly related to the remaining dentin, and because of that, an endodontic treatment can present a higher risk of biomechanical failure. A number of different materials have been used for the manufacturing of dental posts. The fundamental posts requirements include high tensile strength, high fatigue resistance to occlusal and shear loading and a good distribution of the forces affecting the tooth root. The purpose of this article is to review the current literature and identify the various characteristics of a dental post, as well as some principles on the endodontic treatment for tooth decay.

#315 A DFT-based method for 3D digital image correlation

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Abstract The present work describes an approach to digital image correlation (DIC) which is based on calculations performed on the image Fourier domain.

The developed method uses the cross-correlation peak of image subsets computed through the discrete Fourier transform (DFT) to arrive at an estimation of the rigid translation between them, thus enabling the detection of three-dimensional shapes from stereo image pairs and the computation of their displacements between images captured at different loading conditions. The method is expected to offer possible advantages in terms of robustness to lighting conditions, displacement estimation precision, and computational speed.

In order to verify that this method can reproduce results from conventional DIC, images of a quasi-static tensile test of a round specimen are used to compare the values obtained from the DFT based method with the results from commercial software using the traditional intensity field based approach to DIC.

#316 Bone Immobilization devices and consolidation mechanisms: Impact on healing time

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Abstract The human skeleton is formed by living tissues that react to loads and ensures the support of the remaining tissues of human body like muscles, ligaments, tendons, etc. However, its integrity can be compromised due to fractures or injuries of the bone tissue that require orthopedic surgery and immobilization methods, such as external fixators, intramedullary nail or osteosynthesis plates.

One of the most important characteristics of living tissue is its capacity of self-regeneration. It is a complex process that implies several mechanisms during the consolidation time. Therefore, the knowledge of the involved mechanisms and their interdependence on external factors, will allow accelerating the regeneration process and contributing to the success of the rehabilitation process.

Several techniques have been developed to characterizing characterize the mechanical loads acting in fractured bone to better understand the fracture consolidation and obtain useful information for the orthopedic doctors. This information is relevant to enable each patient follow-up and optimize the clinic procedures. As such, it is important to understand what happens during fracture consolidation to predict the necessary structural immobilization time and mechanical stimulus which shorten the healing process.

The purpose of this work is twofold: primarily, to study the consolidation process using different immobilization systems, and secondarily, to explore the necessary time for bone consolidation by recording the relevant mechanical parameters time story.

#317 Structural Characterization of 13th Century Building placed in Trás-os-Montes Region

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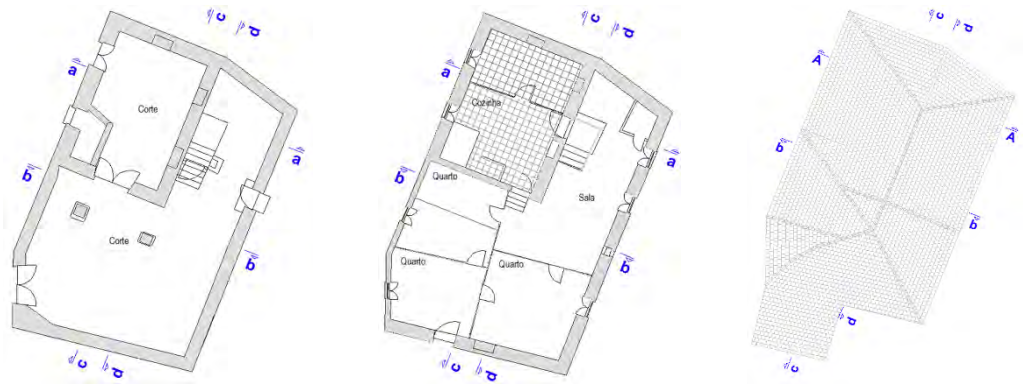
Abstract The objective of this work is the study of the structural characterization of a 13th century building, placed in Trás-os-Montes, Portugal. In the rehabilitation of a building, the study of the architectural and structural plants is very important, being, usually, necessary to do an architectural and structural inspection and mechanical campaign, to characterize the building completely. With the support of the architectural and structural designs it is easier to locate the damages and/or pathologies, understanding the structural behaviour and the influence of the detected damages in the response of the structure, assessing the degree of risk of those damages in the structural stability of the building, leading to a better rehabilitation plan. It is imperative to know the mechanical characteristics of the materials that compose the structures, to repair, and if needed replace them, according to its features, conducting to a sustainable rehabilitation, and preserving the original characteristics



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

***Figure 1** - Architectural survey of the building: (a) basement plant; (b) first floor plant; (c) roof plant.*

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

***Figure 2** – Cuts of the building: (a) cut a-a; (b) cut c-c; (c) cut d-d; (d) cut b-b.*

#318 Numerical Modelling of a Wood Pavement of a 13th Century Building

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Abstract The present work is based on Pousada medieval da Gralheira in Vila Real, Portugal, which is an example of the constructed patrimony of Trás-os-Montes. The negligence in the preservation of historic buildings lead to the current advanced state of deterioration, which implies a complex rehabilitation process. The features obtained in a visual inspection of the building and experimental campaign in wood specimens, made it possible to develop and calibrate a numerical model of the wood floor between the ground and first floors, of the Inn, to analyse the behaviour of the structure in terms of serviceability limit state, so with a numerical model, one can predict the real behaviour of the structure. The numerical models are powerful tools to aid in the structural design.

Figure 1 *– Numerical model of the wood pavement.*

#319 Non-Destructive Structural Wood Diagnosis of a Medieval Building

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Abstract This work seeks to demonstrate the role of non-destructive inspection and diagnosis techniques, trying to find a simple and expeditious supporting decision maintenance/rehabilitation or replacement. The evaluation of the state of conservation of the structures can be made with non-destructive testing to obtain the resistance of the wood structural elements. The case-study is the Gralheira Inn, "Pousada Medieval da Gralheira" in Portugal, which is an example of the antique constructed buildings in the region of Trás-os-Montes. The owners of the heritage buildings neglect it leading to accentuated degradation, making the recovery and rehabilitation interventions, complex. An inspection and diagnosis was carried out to assess the current state of structure conservation and to know the mechanical characteristics, were performed non-destructive tests, using the resistograph and humidimeter.

Figure 1 – Resistograph used in this study.

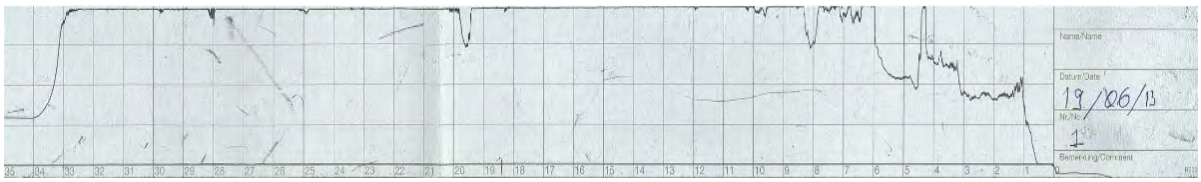

Figure 2 – Obtained graphic of the R1 beam of the pavement, through resistograph.

#320 Material properties of 2024-T3 ALCLAD and 2124-T851 aluminum alloys using 2D and 3D Digital Image Correlation techniques

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Abstract To characterize the rate dependency of materials using various testing machines, specimen geometries of materials are oftentimes required to be modified in order to fit on particular testing machine. Using well stablished standards for static tests may not be a practical choice for high strain rate testing machines such as Split Hopkinson Bar. The scope of this work is to propose and validate modified specimen geometries that could substitute standard geometries. Therefore, series of experiments were carried out on 2024-T3 ALCLAD and 2124-T851 aluminum alloys using Digital Image Correlation technique as a measurement method.

#321 Stress Corrosion Cracking of Progressively Cold-Drawn Pearlitic Steels: From Tintoretto to Picasso

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Abstract Progressive cold drawing in eutectoid steels produces a preferential orientation of the pearlitic microstructure in the wire axis or drawing direction. This affects the posterior behaviour of the steels under conditions of stress corrosion cracking (SCC). The experimental results show that cold drawing induces strength anisotropy in the steel, and thus the resistance to SCC is a directional property that depends on the angle in relation to the drawing direction. Therefore, an initial transverse crack changes its propagation direction to approach that of the wire axis, thus producing mixed mode propagation, the deflection angle being an increasing function of the cold drawing degree. This experimental result may be explained by micro-mechanical considerations on the basis of the lamellar microstructure of the steels. A relationship is established between the microstructural angles and the deflection angles of the macroscopic SCC crack, thus providing a materials science type relationship between the microstructure and the macroscopic crack paths with regard to hydrogen assisted cracking (HAC) associated with the cathodic regime and in the matter of localised anodic dissolution (LAD) linked to the anodic regime. Whereas in hot rolled (not cold drawn at all) and slightly drawn steels the phenomenon of SCC develops in mode I, i.e., the SCC crack is a straight line linked with the classical linear perspective painting by Tintoretto, in the case of heavily drawn steels, the SCC deflected crack is a polygonal line associated with the multi-perspective cubist painting by Picasso, these conclusions being valid for both HAC and LAD.

#322 Hydrogen Effects on Progressively Cold-Drawn Pearlitic Steels: Between Donatello and Michelangelo

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Abstract This paper reviews previous research by the author in the field of hydrogen effects on progressively cold-drawn pearlitic steels in terms of hydrogen degradation (HD), hydrogen embrittlement (HE) or, at the micro-level, hydrogen-assisted micro-damage (HAMD), thus affecting their microstructural integrity and compromising the (macro-)structural integrity of civil engineering structures such as prestressed concrete bridges. It is seen that hydrogen effects in pearlitic microstructure (either oriented or not) are produced at the finest micro-level by plastic tearing in the form, in general, of hydrogen damage topography (HDT) with different appearances depending of the cold drawing degree, evolving from the so-called tearing topography surface (TTS) in hot-rolled (not cold-drawn at all) or slightly cold-drawn pearlitic steels to a sort of enlarged and oriented TTS (EOTTS) in heavily drawn steels (the pronounced enlargement and marked orientation being along the wire axis or cold drawing direction). Whereas the pure TTS mode (null or low degree of cold drawing) resembles the Michelangello stone sculpture texture (MSST), the EOTTS mode does the same in relation to the Donatello wooden sculpture texture (DWST).

#323 Mechanical, Physical and Anatomical Properties of *Cryptomeria japonica* Wood from the Azores

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Abstract Despite the significant number of studies about the properties of *Cryptomeria japonica* wood from the original region in Japan, South of China and Peninsula of Korea, there is a lack of knowledge about the properties of a similar wood species produced in Azores. Therefore, this study aims at characterizing the mechanical, physical and anatomical properties of *Cryptomeria japonica* wood species from Azores, and comparing the properties with same species from other locations. The material used in this study was extracted from 20 grown trees from the S. Miguel Island, from which specimens were produced for the tests. The MOE and MOR were evaluated thru 3-points bending tests, density and anatomical features were also evaluated (width of annual rings (WR) and Latewood Proportion (LP)).

The *Cryptomeria japonica* wood from Azores showed an average MOE of 6938MPa and a MOR of 58 MPa. These properties were obtained for a moisture content of 12% and wood density of 0.38 g/cm^3. The width of the annual rings was about 4.4 mm with 34.7% of latewood proportion. Globally, this species from Azores exhibits better mechanical behaviour, higher density and higher growth rates than verified with species from original region, but also from other regions such as Brazil.

From the mechanical testing, no statistical significant differences were observed between specimens loaded in the TL and those loaded in the RL planes. Positive and significant correlations were verified between the MOR and MOE (r=0.540). Between the mechanical and physical properties, a significant and positive correlation was also found between MOR and density (r=0.809), but not significant correlation was verified between MOE and density (r=0.265ns). As regards the correlations between the WR and the MOR, MOE and Density, despite negatives they were consistently very low (between -0,014 and -0.349) e statistically not significant. The same was observed with the latewood proportion.

#324 Effects of Electrical Discharge Machining on Fatigue Behaviour of AISI D2 Steel

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Abstract Nowadays, competition prevails and the economic problems are a constant issue. It is necessary to look for new ways to produce faster and with better quality with minimum costs. For this reason, companies are looking for ways to deviate from standard procedures and bet on processes that allow working with innovative materials with unique characteristics. It is in this background that Electrical Discharge Machining (EDM) gains emphasis because it can be applied to materials which are difficult or even impossible to machine by conventional methods.

The fatigue phenomenon is mainly superficial and, as such, can be affected by various aspects such as the surface quality of material or the presence of residual stresses at the surface, aspects which may arise in the EDM process. It is in this context that this work fits, in which the main goal is the study of the effects of EDM and the effect of the changes in EDM parameters on the surface of the material, particularly in the fatigue behaviour. For this purpose, the steel for cold working tools, AISI D2, used in components subjected to high wear making part of moulds, is investigated in this work. Specimens are machined by the EDM process using two different sets of parameters and three point bending fatigue tests of rectangular specimens are performed with a stress ratio of 0.1 and their behaviour is compared to the fatigue behaviour of grinded samples.

The results show that the material used has a very heterogeneous microstructure in which there are numerous chromium carbides of high dimensions with a no uniform distribution and arranged vertically in thickness direction of the test pieces, hindering the machining process and negatively affecting the fatigue behaviour of the material. The EDMed specimens show a microstructure characteristic of this process divided into three distinct zones: white layer, heat-affected zone and base metal zone. The white layer shows a very brittle behaviour with a cracking pattern. Also the roughness of the EDMed specimens was higher to the roughness of grinding specimens. The fatigue behaviour is also significantly affected by the parameters used in EDM machining and the EDM process itself, when compared to the grinding process. The grinding specimens showed longer fatigue lives than EDMed specimens. Residual stresses evaluated by XRD on EDMed specimens and grinded specimens were consistent with the distinct fatigue behaviours.

#325 Thermal Analysis of the ITER's Collective Thomson Scattering System

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Abstract The Collective Thomson Scattering (CTS) diagnostic system will be used at ITER to provide spatial and temporal measurements of fast ion velocity distributions. The diagnostic is based on the Collective Thomson Scattering principle, where a microwave beam scatters off electrons in the plasma. The scattered radiation is then collected and measured, providing information about the fast ions. The system components are either considered in-vessel or ex-vessel depending on their location in the port plug. This work consisted on performing a preliminary steady-state thermal analysis to the in-vessel CTS system components using the finite element method. The main goals of this analysis were to analyse the temperature distribution on the components, identify the critical ones and to evaluate the need of implementing an active cooling setup. The in-vessel components are those located in front of the closure plate, where vacuum vessel pressure exists. The CTS in-vessel components include the launcher waveguides, launcher mirrors, launcher mitre bends, receiver mirrors, receiver waveguides and receiver mitre bends. The conceptual CAD model was used and this model was simplified to make it suitable for meshing. The finite element analysis was performed using the commercial finite element software ANSYS v18.0 Mechanical. The in-vessel components were subjected to plasma radiation, stray radiation (radiation not absorbed by the plasma and which is resultant from the operation of the Electron Cyclotron Resonance Heating and the CTS system), nuclear loading due to photons and neutrons, and microwave beam power. The temperatures achieved on the components need to be below the maximum operating temperature of the material in order to meet thermo-structural integrity. The components are all made of stainless steel 316L(N)-IG and the mirrors are also copper coated. To assess the possibility of having to use active cooling on the system, an additional analysis was done using a simplified approach. This approach consisted on introducing convection on the back mirrors surfaces with an estimated convection coefficient. It was observed that, without cooling, the temperatures obtained on the components are much higher than the maximum operating temperature of the material. The plasma facing mirrors and the launcher mitre bend mirrors are the critical components since they reach the highest temperatures. The simplified cooling analysis showed that it is possible to significantly reduce the maximum temperatures obtained. It was concluded that nuclear heating is a major contribution for the primary receiver mirror which is the plasma-facing mirror closest to the drawer opening and that the microwave beam power absorbed by the launcher mirrors has a significant contribution to the temperatures reached. It was also concluded that an active cooling setup needs to be designed to meet structural integrity. The work leading to this publication has been partially funded by Fusion for Energy under the Specific Grant F4E-FPA-393-SG04. This publication reflects the views only of the author, and Fusion for Energy cannot be held responsible for any use which may be made of the information contained therein. Additionally, IPFN activities received financial support from "Fundação para a Ciência e Tecnologia" through project UID/FIS/50010/2013.

#326 Thermal structural analysis of ITER's Collective Thomson Scattering launcher mirror

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Abstract: The Low Field Side Collective Thomson Scattering system (LFS-CTS) provides measurement of plasma parameters related to the ion velocity distribution function. The diagnostic is based on the Collective Thomson Scattering principle, where a powerful mm-wave beam (60GHz, 1.0MW gyrotron), scatters off electrons in the plasma. The diagnostic consists of several components such as transmissions lines and front-end components such as mirrors to launch the probe beam into the plasma region and to collect radiation. This paper presents the thermal-structural integrity analysis of the launcher mirror. This component is under heavy thermal loading conditions since it is directly facing the plasma, which provides a heat flux of 500kW/m^2 and a neutron load generating 1.5 W/cm^3 of internal heat. In addition, a fraction of the 1MW mm-wave beam is absorbed by the material. The goals of this analysis were to assess and limit the temperature distribution across the component, to evaluate the need of implementing active cooling and to compute and limit the thermal stresses. An initial steady-state thermal analysis was performed assuming the use of 316L(N)-IG stainless steel to evaluate if active cooling was needed. Since the computed temperature distribution was higher than the material limit, it could be concluded that active cooling had to be implemented. Several cooling channel geometries were developed and a new set of steady-state thermal analysis was performed to compare the several arrangements. The cooling setups were modeled using pipe elements allowing fluid flow and heat exchange. For each geometry, several mass flow rate values were considered up to an allowable maximum of 1.5kg/s. The heat coefficient, being dependent on geometry and flow properties, was calculated for each setup. Considering the use of active cooling, it was shown that is possible to have a peak temperature below the material limit for the stainless steel mirror. However, since the mirror showed high thermal gradients, it also presented high thermal stresses (above the elastic limit in several regions). To face this issue, additional materials with a higher conductivity were considered to reduce the thermal gradients across the component. Tungsten and the CuCrZr alloy were chosen and a new set of analysis was done.This work shows that by using materials with high thermal conductivity and adequate mechanical properties for the launcher mirror, it is possible to achieve peak temperature values below the materials limits and an even temperature distribution across the component, leading to lower thermal stresses (below the elastic limit) than in the stainless steel case, thus assuring the thermal-structural integrity. The work leading to this publication has been partially funded by Fusion for Energy under the Specific Grant F4E-FPA-393-SG04. This publication reflects the views only of the author, and Fusion for Energy cannot be held responsible for any use which may be made of the information contained therein. Additionally, IPFN activities received financial support from "Fundação para a Ciência e Tecnologia" through project UID/FIS/50010/2013.