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PREFACE

Dear Colleagues, Dear Friends,

It is with great pleasure that we welcome you to our beautiful city of Belgrade (Serbia) for the 1st edition of the Biennial ESIS-CSIC Conference on Structural Integrity (BECCSI 2025). But first, a couple of words about the organisers of this international scientific event - the European Structural Integrity Society, the China Structural Integrity Consortium and the co-organiser, the Society for Structural Integrity and Life "Prof dr Stojan Sedmak".

The China Structural Integrity Consortium (CSIC) is a non-profit academic organization committed to promoting academic exchanges, advancing scientific research, facilitating engineering applications, and disseminating knowledge specifically in the realm of structural integrity. Its origins can be traced back to 2002, spearheaded by a consortium of universities and research institutes that have historically participated in joint research focused on structural integrity, especially concerning the safety technology of pressure vessels and pipelines. In 2003, the inaugural International Fracture Mechanics (FM) Symposium took place in Shanghai. As the discipline and its application areas broadened, the FM series of conferences transitioned in 2010 to the International Symposium on Structural Integrity (ISSI), with member institutions rotating the responsibility of organization. In November 2012, following extensive discussions and consultations among the Materials Division, Pressure Vessel Division, and Failure Analysis Division of the Chinese Society of Mechanical Engineering, the decision was made to collaboratively establish the CSIC. The latest ISSI took place in Dongguan from November 5th to 8th, 2024.

The European Society for Structural Integrity (ESIS) is an esteemed international non-profit engineering scientific society. Its primary mission is to foster and enhance knowledge surrounding all facets of structural integrity and to disseminate that knowledge widely. The overarching goal is to elevate the safety and performance of structures and their components. The origins of the European Structural Integrity Society can be traced back to November 1978 during a summer school event in Darmstadt, Germany. Initially, it was known as the European Group on Fracture. From 1979 to 1988, several technical committees were established, with the Elasto-Plastic Fracture Mechanics committee being the first among them. The initial vision was to emulate the work of the ASTM committee in Europe. Dr. L.H. Larsson from the European Commission Joint Research Centre served as the inaugural president of the European Structural Integrity Society. Currently, ESIS comprises a total of 24 technical committees and national groups across all European countries. The present president of ESIS is Prof. Aleksandar Sedmak from the University of Belgrade in Serbia.

The Society for Structural Integrity and Life (Serbian Društvo za integritet i vek konstrukcija "Prof. Dr. Stojan Sedmak", or simply DIVK) is a non-governmental, non-profit society of experts engaged in the practical application of the theory of fracture mechanics. Founded in 2001, today the Society has more than 240 registered members and engages in a number of activities such as seminars, publications, cooperation with other societies, and more. The journal "Structural Integrity and Life" is published by DIVK.

The Society aims to master contemporary theoretical, numerical, and experimental methods for structural integrity assessment in order to apply them to ensure in-service safety and reliability and to extend their design life, enable the prevention of failures to minimize the risk of endangering human lives and polluting the environment, and improve the level of education and publishing in the field.



1st Biennial ESIS-CSIC Conference on Structural Integrity
(BECCSI 2025)

November 25-28, 2025, Belgrade, Serbia

The editors of the Proceedings of the 1st Biennial ESIS-CSIC Conference on Structural Integrity - BECCSI 2025 (Book of Abstracts),

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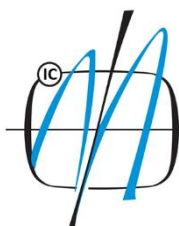
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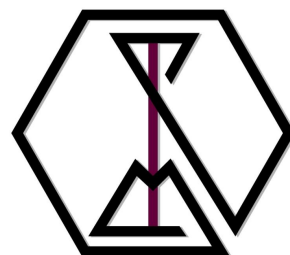


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Fracture mechanics based design of super-low ice adhesion surfaces
- **Filippo Berto**, Sapienza University of Rome, Department of Chemical Engineering, Materials and Environment, Italy
Additive manufacturing, current trends and future opportunities
- **Lixun Cai**, School of Mechanics and Aerospace Engineering, Southwest Jiaotong University, Chengdu, China
Analytical Mechanical Theory and High-Throughput Indentation Instrument
- **Sabrina Vantadori**, Department of Engineering & Architecture, University of Parma, Italy
Francesco Iacoviello, University of Cassino and Southern Lazio, Department of Civil and Mechanical Engineering, Italy
From metals to nanomaterials: A comprehensive approach to fracture toughness assessment
- **Jacque Besson**, MinesParis PSL, Centre des Matériaux CNRS, France
Simulation of ductile rupture: from micromechanics to structural failure
- **Wanlin Guo**, State Key Laboratory of Mechanics and Control for Mechanical Structures, Nanjing University of Aeronautics and Astronautics, Nanjing, China
Three-dimensional fatigue fracture mechanics: Bridge the gap from laboratory to engineering Structures
- **Binhan Sun**, East China University of Science and Technology, Shanghai, China
How hydrogen damages Ni-based alloys at elevated temperatures
- **Miloš Đukić**, University of Belgrade, Faculty of Mechanical Engineering, Serbia
Hydrogen embrittlement mechanisms in metals: New insights
- **Tong Liu**, School of Mechanical and Power Engineering, Shanghai China
Nuclear fuel cladding degradation: Embrittlement visualization of Cr-Coated zircaloy

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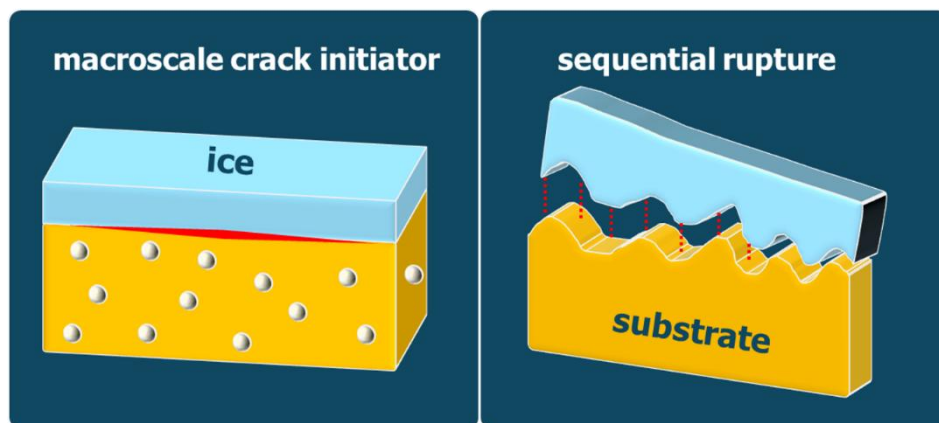
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Abstract

Ice accumulation poses significant challenges in industries such as aviation, transportation, and energy. While studies on suppressing ice nucleation by surface structuring and local confinement are highly desired, a realistic roadmap to icephobicity for many practical applications is perhaps to live with ice, but with the lowest possible ice adhesion. This talk explores the possibility of reducing ice adhesion by designing low-adhesion surfaces using fracture mechanics concept, inspired by biological systems and engineered solutions. By rationalizing crack initiation at multiple scales—nano (NACI), micro (MICI), and macro (MACI)—we demonstrate how to amplify interfacial crack driving forces and weaken ice–substrate bonding. A macro-crack initiator (MACI) mechanism is proposed, which significantly reduces ice adhesion by enhancing crack propagation at the ice-substrate interface across multiple length scales. The anisotropic ice adhesion behavior of Arctic salmon skin is also demonstrated, showing a reduction of up to 60% in ice adhesion when sheared along a specific direction. By leveraging biological insights and engineering strategies, we offer new possibilities for designing hard and durable anti-icing surfaces, opening new avenues for understanding and designing surfaces with tailored adhesion mechanics.



Keywords: Crack initiator; sequential rupture; ice adhesion; icephobicity

Acknowledgement

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ADDITIVE MANUFACTURING, CURRENT TRENDS AND FUTURE OPPORTUNITIES

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Abstract

The talk will be dedicated to recent trends in additive manufacturing focusing on recent developments, especially for metallic materials. Fracture and fatigue assessment plays a fundamental role for the future of these new materials and the lecture will focus on these aspects showing new design opportunities and advanced methods for optimizing additively manufactured components. Data driven methods are a powerful tool in this regard and some considerations will be carried out showing the most updated solutions up to now available.

Keywords: Additive manufacturing; fatigue; Data-driven methods

ANALYTICAL MECHANICAL THEORY AND HIGH-THROUGHPUT INDENTATION INSTRUMENT

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Abstract

The establishment of original principle-based theories and their expansion in experimental methodology systems play a decisive role in developing novel technologies for mechanical testing of small specimens and advancing scientific instrument innovation. Since achieving theoretical breakthroughs in 2016, our research team (led by Prof. Cai Lixun) has systematically established an analytical theoretical system for specimen-oriented elastoplastic mechanics based on the original energy density equivalence principle. This has enabled the successful development of a high-throughput mechanical testing method with robust theoretical foundations. By translating theoretical innovation into technological practice, we have overcome the technical bottlenecks of traditional mechanical testing in methodology, efficiency, and accuracy, completed the independent R&D of advanced high-throughput indentation instruments, and realized commercialization. These instruments have been applied across multiple fields including nuclear power, aerospace materials, material preparation, and service performance detection, highlighting their significant advantages in rapid material performance evaluation.

Keywords: Energy density equivalence; Analytical theory; Small specimens; Mechanical testing; High-throughput indentation; Indentation instrument

FROM METALS TO NANOMATERIALS: A COMPREHENSIVE APPROACH TO FRACTURE TOUGHNESS ASSESSMENT

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Abstract

Fracture toughness is a critical mechanical property that quantifies a materials ability to resist crack propagation under applied stress. Its determination is essential for ensuring the safety, reliability, and durability of structures and components in industries such as aerospace, automotive, civil engineering, and medical devices. Standardized experimental methods, including those based on Linear Elastic Fracture Mechanics (LEFM) and elastic-plastic approaches, allow for the measurement of key parameters such as KIC, which represents a material intrinsic resistance to fracture. Understanding fracture toughness helps engineers prevent catastrophic failures, optimise material selection, and improve structural performance. Moreover, it plays a crucial role in predicting service life, reducing maintenance costs, and enhancing sustainability by minimising material waste and failure-related risks. The accurate assessment of fracture toughness contributes to safer and more efficient designs, making it a fundamental aspect of modern engineering and material science.

In such a context, the present research aims to provide a comprehensive overview of fracture toughness testing across a broad spectrum of materials, ranging from traditional ones - such as metals, metal alloys, mortar, and concrete - to innovative materials, including reinforced mortar, reinforced concrete, reinforced pervious concrete, earth-based material and nanomaterials. The study is conducted at different length scales, addressing both macroscopic and nanoscale behaviours, which are crucial for understanding material failure mechanisms in different applications.

A key focus of this lecture is the presentation of well-established testing methods and novel approaches, which offer improved accuracy and applicability for emerging materials. In particular, novel methodologies for determining the fracture toughness of both quasi-brittle materials and nanomaterials are presented.

Keywords: Fracture Toughness; Engineering Applications; Material Characterization

Acknowledgement

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SIMULATION OF DUCTILE RUPTURE: FROM MICROMECHANICS TO STRUCTURAL FAILURE

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Abstract

Since the pioneering work by Rice and Tracey (1969) and Gurson (1977), the micromechanical description of ductile damage from nucleation to final failure has been widely developed and adopted. Numerous extensions of the Gurson-Tvergaard-Needleman model (1984) have been and are still proposed. These are nowadays implemented in finite element codes. Using standard displacement-based formulations, these models lead to a strong mesh dependence (on element size, element type, element shape and orientation, ...). This implies that complex situations where the crack path changes cannot be analyzed in a robust and reliable way. These problems can be solved using so-called 'nonlocal' formulations, of which many types exist. The different versions of these models are now employed to simulate laboratory-size specimens. These usually include notched bars and pre-cracked specimens (e.g. Compact Tension or Single Edge Notch Tensile specimens). However, a major remaining challenge is the assessment of the integrity of critical mechanical components such as nuclear pressure vessels or pipelines containing potential defects. The use of damage models could be of particular interest in situations where standard assessment procedures based on global parameters (J-integral, Q-factor) are not applicable. This is the case of complex geometries, welds, or structures which do not initially contain cracks. The presentation will review the state-of-the-art of ductile damage modeling and illustrate the capabilities of these models to analyze the integrity of large-scale structures. The remaining challenges will be discussed.



Example of a full-size test

Keywords: Ductile rupture; GTN model; Finite element simulation; Full-size test

THREE-DIMENSIONAL FATIGUE FRACTURE MECHANICS: BRIDGE THE GAP FROM LABORATORY TO ENGINEERING STRUCTURES

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Abstract

This talk reviews advances in three-dimensional (3D) fatigue fracture mechanics, bridging laboratory research and engineering applications. It highlights limitations of traditional fatigue life and damage tolerance design methods and presents the development of 3D constraint theories. Key progress includes extensions from 2D to 3D analysis, tensile to mixed-mode loading, static to fatigue/creep fracture, and ambient to high-temperature conditions. These contributions provide a theoretical foundation for predicting fatigue life and ensuring structural durability and reliability.

Keywords: Three-dimensional Fatigue Fracture; Damage Tolerance; Constraint Theory; Crack Growth; Durability Design

HOW HYDROGEN DAMAGES Ni-BASED ALLOYS AT ELEVATED TEMPERATURES

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Abstract

Structural components in the fields of H energy applications (e.g. H₂ gas turbines) can be subjected to a wide range of exposure temperatures. Despite extensive research on H embrittlement at near room temperature, the H-induced damage behavior in Ni-based superalloys at elevated temperatures remains unknown. Here we study the influence of temperature on H-induced damage mechanisms in a Ni-based Inconel 718 alloy subjected to in-situ tensile testing under gaseous H₂ environment up to 600 °C. The detrimental effect of H on ductility was found to be pronounced at the temperature range from 25 to 400 °C, whereas such effect is moderate at 600 °C for the tested H₂ pressure and strain rate. At the temperature of 25 and 200 °C, both H-induced intergranular and transgranular fracture were observed, which are associated with δ/γ -matrix interface decohesion and δ phase cracking. A higher proportion of δ/γ -matrix interface decohesion due to H was observed at 200 °C compared with the cracking scenario at 25 °C, which can be attributed to the higher H diffusivity and thus more H accumulation at local microstructural trapping sites. The H-induced damage behavior is markedly different at 400 °C, at which Ti-based carbides cracking become the prevalent damage mode. Detailed characterizations indicate the H-induced transition of these carbides at this temperature. The underlying mechanisms and their impact on damage evolution are further discussed.

Keywords: H-induced damage; Ni-based superalloys; characterization

HYDROGEN EMBRITTLEMENT MECHANISMS IN METALS: NEW INSIGHTS

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Abstract

The unified HELP+HEDE model is a comprehensive concept that explains the synergy of hydrogen embrittlement (HE) mechanisms in metallic materials. This model involves the interplay and competence between two groups of HE mechanisms: HELP and/or other plasticity-mediated HE mechanisms, and the HEDE mechanism. The confirmed competition and transition in dominance between hydrogen provoked localized plasticity, i.e., hydrogen-induced dislocation activity (HIDA), HE mechanisms (HELP and others), and HEDE, depending on the global/local hydrogen (H) concentration and distribution, microstructural characteristics, and stress state, are of utmost importance to achieve a unified model for HE in metals. The recently updated unified HELP+HEDE model introduced the novel concept of "local HEDE micro-incidents," which refers to the appearance of discrete micro-scale incidents, i.e., hydrogen-induced crack initiation, at a high local H concentration above the critical one, particularly at "HEDE-prone H traps" within the microstructure. For the shift from HELP to HEDE macroscopic predominance, followed by a sharp drop in ductility, the necessary prerequisite is the macro-volume appearance of "local HEDE micro-incidents". In that case, the degree of activity of the HELP mechanism and other plasticity-mediated (HIDA-type) HE mechanisms can become negligible. This talk presents new insights into the unified HELP+HEDE model, including the innovative concepts of "local HEDE micro-incidents" and "HEDE-prone H traps", which highlight its significance in the fundamental understanding of HE phenomena in metals.

Keywords: Hydrogen embrittlement; Metallic materials; HELP; HEDE, Hydrogen-induced crack initiation

NUCLEAR FUEL CLADDING DEGRADATION: EMBRITTLE- MENT VISUALIZATION OF Cr-COATED ZIRCALOY

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Abstract

Chromium-coated Zircaloy, having been implemented as lead test assemblies (LTAs) in commercial reactors and approaching full commercialization, represents a leading accident-tolerant fuel (ATF) cladding material. However, a comprehensive understanding of its embrittlement behavior and underlying mechanisms under severe accident conditions remains essential. In this work, a combined approach employing integrated in-situ techniques (DIC, high temperature oxidation, ballooning-burst tests, RCT) and ex-situ microstructural characterization (EBSD/SEM) was utilized to visualize the embrittlement process, correlating macroscopic mechanical response with underlying microstructural evolution. Dynamic oxidation monitoring successfully captured the initiation of the critical Cr–Zr eutectic reaction along with the progressive development of a distinctive "crocodile-skin" surface morphology. Samples oxidized at 1200 °C maintained excellent oxidation resistance but suffered significant embrittlement. In contrast, claddings oxidized at 1350 °C not only preserved superior oxidation resistance compared to uncoated Zircaloy but also exhibited noticeably reduced embrittlement. Detailed microstructural analysis attributed this anomalous behavior to the formation of a columnar-grained eutectic structure and associated interfacial crack propagation. The eutectic reaction was confirmed to degrade mechanical properties primarily through the precipitation of hard-brittle intermetallic phases and the nucleation and growth of microcracks. These findings offer critical visual evidence and mechanistic understanding of cladding embrittlement, providing valuable insights for the safety assessment and performance optimization of Cr-coated ATF claddings under severe accident scenarios.

Keywords: Cr-coated zircaloy, Cladding, Embrittlement, Eutectic reaction, Ballooning-burst tests

SPECIAL LECTURES

- Z. Zhang, Norwegian University of Science and Technology (NTNU), Trondheim, Norway
Some insights into micromechanical modelling
- H. Luo et al, University of Science and Technology Beijing, China
Environmental degradation and mechanisms of multi-principal element metallic materials
- Z. Qian, Wuhan Institute of Technology and Shenzhen University, China
Viscoplasticity with damage evolution for reliability engineering
- A. Sedmak, University of Belgrade, Faculty of Mechanical Engineering
Direct measurement of J integral – Origin, applications and perspectives

SOME INSIGHTS INTO MICROMECHANICAL MODELLING

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Abstract

Micromechanical modelling provides a powerful framework for linking material microstructure with macroscopic performance. In this talk, I will share some insights into the principles and applications of micromechanical approaches. Key questions will be considered: What is micromechanical modelling and what purposes does it serve? What types and numbers of parameters are essential? Which intrinsic parameters truly drive fracture, and which arise naturally as consequences of the deformation process? To what extent are the model parameters transferrable across different systems? By addressing these issues, I aim to highlight the potential and the limitations of micromechanical modelling, and to stimulate discussion on its role in advancing predictive tools for assessing material and structural integrity.

Keywords: Micromechanical modelling; predictive tools; structural integrity; fracture

ENVIRONMENTAL DEGRADATION AND MECHANISMS OF MULTI-PRINCIPAL ELEMENT METALLIC MATERIALS

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Abstract

Multi-principal element high-entropy alloys (HEAs) have emerged as promising candidates for next-generation structural materials owing to their unique compositional design and excellent combination of mechanical strength and corrosion resistance. However, their hydrogen embrittlement behavior and underlying mechanisms remain to be fully clarified. In this work, we systematically investigated the mechanical properties and failure behavior of multi-component HEAs in hydrogen-containing environments, based on our group's recent research. By employing in-situ hydrogen charging tensile tests, slow strain rate tests, transmission electron microscopy, and three-dimensional atom probe, we revealed the diffusion, accumulation, and trapping mechanisms of hydrogen in HEAs. Combined with first-principles calculations and molecular dynamics simulations, the effects of alloying composition, lattice distortion, and multiscale defects on hydrogen embrittlement susceptibility were elucidated. The results demonstrate that appropriate multi-element alloying can introduce diverse hydrogen trapping sites, retard crack propagation, and thus effectively improve HE resistance. This study provides both theoretical insights and experimental evidence for the design of high-strength, hydrogen-resistant HEAs.

Keywords: hydrogen embrittlement; high-entropy alloys; microstructure; environmental degradation

VISCOPLASTICITY WITH DAMAGE EVOLUTION FOR RELIABILITY ENGINEERING

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Abstract

We have developed a unified constitutive model for viscoplasticity with damage evolution. This model has been established since author's PhD dissertation accomplished in China. We have followed the internal variable theory established by Jim Rice. We have specified the back stress as key internal variable for plasticity defined by dislocation dynamics and also by crystal slip theory. Second internal variable called drag stress is adopted for viscoplastic effects. Third internal variable for damage evolution is introduced by Gurson model based on voiding mechanism. The evolution equations of three internal variables are well established. Moreover, the return-mapping algorithm for the unified viscoplastic constitutive model is well developed and implemented in ABAQUS as user subroutine in the United States. The viscoplastic model is first verified by the creep and plastic behaviors of stainless steels at high temperatures. Its powerful capability is furthermore demonstrated by the failure mechanism and failure modes of solder alloys used in mobile devices. The last case study is to utilize the model to bolted flange connections for addressing their reliability issues.

Keywords: viscoplasticity; return-mapping algorithm; back stress

DIRECT MEASUREMENT OF J INTEGRAL – ORIGIN, APPLICATIONS AND PERSPECTIVES

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Abstract

Direct measurement of J integral has been presented as a retrospective of more than 40 years of experience. Early efforts and experiments on welded wide plates and pressure vessels are presented and analysed in respect to the effect of material heterogeneity. Physical meaning of the J integral values obtained by direct measurements on a pressure vessel is explained to clarify its application. Different boundary conditions are also considered, to investigate options for simplified measurements. The possibility of applying simplified direct measurement of J integral for pressure vessel integrity assessment has been considered. Using favourable boundary conditions, J integral value is reduced to strain energy on the opposite side of the crack-like defect, which is often the case with pressure vessels. Such measurement can be easily performed during proof testing of a vessel. Finally, it is noted that the measurement of strains by digital image correlation instead of strain gauges can make a new life of this technique.

Keywords: J integral; integrity assessment; pressure vessel; digital image correlation

STRUCTURAL INTEGRITY FOR ADVANCED MANUFACTURING

- D. Chauhan, M. Sahni - *Tribological optimization of ultrasonically stir-cast quasi-isotropic composites reinforced with carbide and sulfide using the Box–Behnken design*
- T. Mazarire, A. Galloway, A. Toumpis - *Hydrogen embrittlement of WAAM AA2319: Tensile properties and fracture analysis*
- K. Monkova, P. P. Monka, P. Beňo, A. Sedmak - *Stiffness and modulus of resilience of selected ABS lattice structures*
- Z. Golubović, B. Bojović, J. Tanasković - *Research of Voronoi lattice PLA resin structures for patient-specific orthopedic immobilization*
- C-F. Popa, S.V. Galațanu, L. Marșavina, O. Pop - *Effects of raster orientation and notch insertion on fracture toughness of PETG*
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- M. Pavlović, M. Dojčinović, E. Kurtanović, I. Marković - *Development of coatings for the protection of metals structures based on pyrophyllite, zeolite and talc*
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- M. Manjgo, J. Bernetič, G. Lojen, T. Vuherer - *Assessment of welded joint integrity of armour steel SA 500 based on fracture mechanics parameters*
- Z. Xu, A. Sarkar, R. Branco, S. Wronski, J. Tarasiuk, L. Borrego, N. Razavi - *Influence of geometric factors and process-induced attributes on the monotonic and fatigue behavior of AlSi10Mg TPMS lattices: Impact of scale, unit cell size and wall thickness*
- Y. Ma, W. Sun, X. Sun - *Fatigue fracture behavior of additively SLM manufactured titanium alloy super structures*
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- S. Murchio, P. Gallo, A. Fabrizi, M. Benedetti, F. Berto - *Fatigue behavior of miniaturized Ti-6Al-4V lattice struts: comparing continuous and pulsed wave L-PBF*
- V. Raspudic, A. Coralic, M. Manjgo, T. Vuherer - *Influence of fibre orientation on the reduction of mechanical properties in injection-moulded test specimens*
- Me. Manjgo, V. Raspudić, Mi. Manjgo - *Fracture toughness analysis of a welded joint on high-strength steel*
- M. Bannikov, Y. Bayandin, A. Nikityuk, S. Uvarov, O. Naimark - *Experimental field analysis of damage-failure transition in composite material with a stress concentrator under cyclic loading (application of DIC and X-ray tomography techniques)*
- Y. Xu, R. Wang, Y. S. Sato, K. Suzuki, Y. Zhao, Z. Yi, A. Wu - *Fabrication of multi-material structures from austenitic to ferritic stainless steels via dual-wire arc additive manufacturing*
- N. Ilić, M. Kalajdžić, N. Momčilović - *Structural modification of the cargo hold double bottom for a multi-purpose vessel*
- S. Lomov - *Quantification of defects in fibre reinforced composites based on an XCT image*
- A. Milovanović, S. Sedmak, J. Poduška, K. Čolić, A. Sedmak - *Fatigue behaviour of FDM-printed orthopaedic plates with varying infill densities*

- I. Trajković, M. Milošević, B. Međo, D. Veljić, J. Šaković-Jovanović - *Examination of fracture resistance of polymer materials using new ring tensile specimens*
- Y. Chen, T. Lu, X. Chen, B. Sun, N. Yao, K. Li, J. Qiu, X. Hu, X.-C. Zhang, S.-T. Tu - *Optimized bilateral surface ultrasonic rolling technology assisting directed energy deposition of thin-walled medium-entropy alloy with high mechanical performance*
- S. Lohrasbi, S. Nakhodchi, S. Hadidimoud - *The effect of pre-strain on the strength of selective laser melted (SLM) inconel 718*
- E.S. Apostolopoulos, X. Zhang, S. Hadidimoud - *Influence of end geometry and defects on structural integrity of a light-weight composite strut*
- N. Ogunlakin, E. S. Al-Zahrani, I. U. Toor - *Influence of heat treatment on hydrogen-induced cracking susceptibility of API 5L X60 pipeline steel evaluated in accordance with nace TM0284 standard*
- N. Gubeljak, A. Likeb, D. Damjanović, D. Kozak, L. Ferlič - *Fracture behavior pipe-ring specimens for fracture toughness testing of thin-walled pipelines*
- D. Damjanović, N. Gubeljak, D. Kozak, M. D. Chapetti - *Analytical and numerical stress analysis on ring specimens for fracture toughness testing*
- Z. Liu, L. Zhang, X. Chen - *Experimental and simulation study on fracture toughness of fiber-reinforced composites*
- H. M. A. Abdalla, F. de Bona, D. Casagrande - *Stress concentration optimization for functionally graded plates with a pair of circular holes*
- M. Sedlaček, B. Šetina Batič, B. Zajec, A. Legat, I. Paulin, F. Martin Franz, B. Podgornik - *Hydrogen-induced changes in mechanical properties and fatigue life of additively manufactured stainless steels*
- T. Lazović, M. Dojčinović, D. Popović, M. Stojanović - *Influence of layer height on cavitation rate of 3D-printed PLA*
- X. Zhang, Z. Li, Y. Xiao, Q. Lin, Y. Xiao, Y. Tian, B. Wang - *AI-driven optimization of 3D-printed short carbon fiber-reinforced composite grid structures*
- D. Bajić, A. Alil, M. Lazarević, J. Marinković, N. Ilić - *Explosively welded steel bi-layers interfacial integrity and cavitation erosion resistance*
- N. Milošević, I. Trajković, A. Maslarević, M. Milošević, F. Mercuri - *The effect of natural aging on the tensile properties of PETG-CF filament*
- M. Balać, A. Grbović, L. Sarvaš - *Numerical assessment of structural integrity and fatigue behavior of a mechanism for transporting the platform for passengers with reduced mobility*
- D. Pradhan, S. Ranjan Sahoo - *An investigation on C. elegans inspired auxetic structures*
- D. Momčilović, I. Atanasovska - *Corrosion induced failure of gas cylinder – two case studies*
- A. Bacco, F. Berto, R. Sepe - *The effect of welding process on static and fatigue behavior of high-strength steel welded joints*
- A. Đurić, D. Perišić - *Conductive polymers*
- M. Bragagila, A. Ceci, L. Corradi, G. Costanza, M. E. Tata - *Optimization of the debinding and sintering process of FFF 3D-printed AISI 316L samples*
- M. Travica, D. Miljković, A. Đurićin, N. Mitrović - *Integrated 3D DIC and PRTS analysis of long-term degraded power plant steel*
- M. Travica, D. Miljković, N. Mitrović - *Dimensional accuracy assessment of 3D-printed CT specimens produced by selective laser sintering*

TRIBOLOGICAL OPTIMIZATION OF ULTRASONICALLY STIR-CAST QUASI-ISOTROPIC COMPOSITES REINFORCED WITH CARBIDE AND SULFIDE USING THE BOX-BEHNKEN DESIGN

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Abstract

The present work focuses on improving the tribological performance of quasi-isotropic composites reinforced with carbide and sulfide particles. These composites were fabricated through an ultrasonically assisted stir casting process to achieve uniform particle dispersion and enhanced interfacial bonding. The influence of key operating parameters such as normal load, sliding speed, and temperature on surface degradation and frictional resistance was examined using the Box–Behnken Design (BBD) design. Experimental trials were conducted on a pin-on-disc setup, and the obtained data were analyzed using response surface methodology and statistical validation was conducted through ANOVA. The results indicate that the interaction of load and temperature significantly affects the wear mechanism, while the addition of sulfide phases improves the self-lubricating behavior. Optimal process conditions were identified to minimize surface degradation and frictional resistance. This demonstrates that integrating ultrasonic stirring with BBD-based optimization is effective. It provides an efficient pathway for developing high-performance tribological materials suitable for demanding engineering applications.

Keywords: Box–Behnken Design; Carbide–sulfide reinforcement; Frictional resistance; Surface degradation; Ultrasonic stir casting

HYDROGEN EMBRITTLEMENT OF WAAM AA2319: TENSILE PROPERTIES AND FRACTURE ANALYSIS

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Abstract

Hydrogen embrittlement is a phenomenon characterised by the degradation of mechanical properties in materials exposed to hydrogen-rich environments. This study investigates the effects of hydrogen charging conditions on the tensile properties of AA2319 fabricated via wire arc additive manufacturing. Hydrogen was introduced into the tensile specimens via cathodic charging in an electrolyte containing 3.5wt% NaCl and 3g/L ammonium thiocyanate. Hydrogen embrittlement was systematically evaluated by applying varied charging current densities. Tensile testing revealed reduced elongation and ultimate tensile stress with increasing charging current density. Fractographic analysis revealed brittle fracture morphology which is consistent with hydrogen-induced embrittlement. Corrosion products were observed on the fracture surfaces of the charged specimens, attributed to the interaction between the aluminium and the charging electrolyte. These findings provide insights into the susceptibility of additively manufactured AA2319 to hydrogen embrittlement and its potential implications for structural applications.

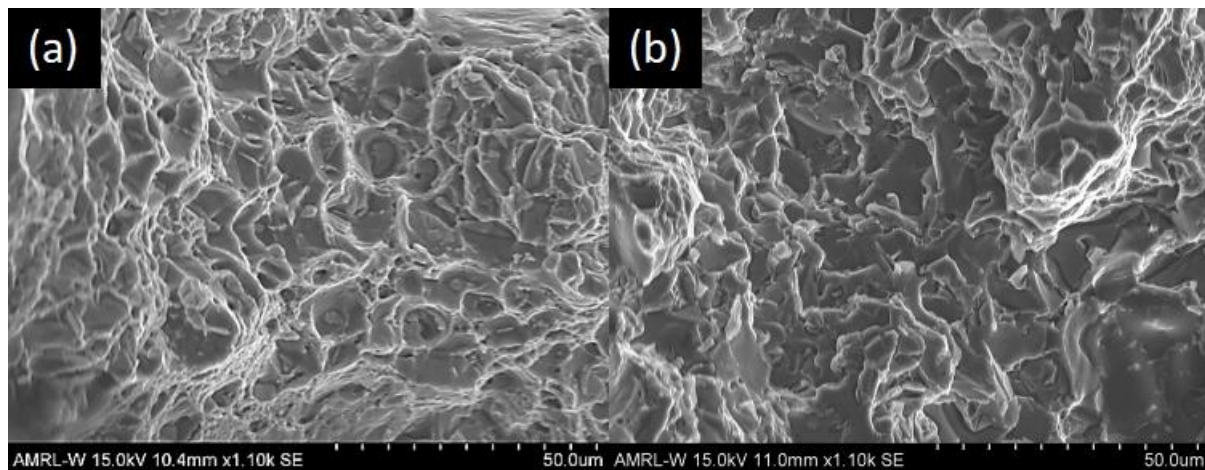


Figure 1: Fractography results of (a) uncharged specimen with dimple fracture (b) charged specimen showing brittle fracture

Keywords: Hydrogen embrittlement; WAAM; hydrogen charging; aluminium alloy 2319; fractography

STIFFNESS AND MODULUS OF RESILIENCE OF SELECTED ABS LATTICE STRUCTURES

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Abstract

Additive production makes it possible to produce surfaces with complex shapes which are difficult to produce by conventional methods of production. One of these groups of so-called metamaterials also includes cellular lattice materials.

The article deals with investigation of the influence of volume fraction on the stiffness and modulus of resilience of four selected types of cellular structures under bending load until failure. The test samples were manufactured using the Fused Filament Fabrication (FFF) technique from ABS material, which is one of the most widely used plastics suitable for the production of components with a wide range of technical and consumer uses. Five samples of each type were manufactured (given by the geometry of the structure and the volume fraction of the material, so a total of 60 samples were manufactured). For the porous part of the sample itself, a diameter of 25 mm and a length of 90 mm were selected, while the total length of the samples with the end parts for clamping in the tested machine was 200 mm. Bending tests to failure were performed on a Zwick 1456 universal testing machine. As expected, the mechanical property values increased with volume fraction, while a comparison of structures with the same volume fraction showed that the Starlit type samples showed the best stiffness, but from the point of view of modulus of resilience, the Octagonal structure dominated.



Figure 1. Example of a sample for testing

Keywords: lattice structure; ABS material; stiffness; modulus of resilience, failure

Acknowledgement

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RESEARCH OF VORONOI LATTICE PLA RESIN STRUCTURES FOR PATIENT-SPECIFIC ORTHOPEDIC IMMOBILIZATION

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Abstract

Additive manufacturing opens up new possibilities for the design of biomedical devices and facilitates the production of lightweight, ventilated and fully customized supports. In this paper, experimental investigations and numerical simulations of solid and Voronoi-structured PLA resin specimens fabricated with digital light processing (DLP) were performed. Previous studies have shown that Voronoi structures are lighter and more flexible than solid ones, while developed numerical models can reliably predict their behavior under different loads and deformation modes, i.e. elongation and bending. This research demonstrates how these proven methods can be applied to orthopedic immobilization devices such as immobilizers and braces. The approach suggests that Voronoi structures can reduce weight and improve comfort by allowing better ventilation without losing the stiffness required to stabilize an injured limb. Based on the experimental results the developed numerical models are validated. A practical pathway for the next generation of patient-specific orthopedic supports can be identified, bringing these concepts closer to clinical use.

Keywords: Additive manufacturing; Voronoi; orthopedic immobilizers; PLA resin; DLP; experimental research; numerical model

Acknowledgement

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EFFECTS OF RASTER ORIENTATION AND NOTCH INSERTION ON FRACTURE TOUGHNESS OF PETG

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Abstract

The Fused Deposition Modeling (FDM) is the most widely used additive manufacturing technique due to its efficiency, ease of material exchange, and capability to manufacture complex geometries. This study aims to evaluate the fracture toughness K_{IC} for PETG specimens FDM manufactured with different configurations and raster angles (0°, 45°, and 90°). For contoured specimens, a pre-crack was introduced using a 0.03 mm diameter wire, creating pre-cracks between 1–2 mm in length. The results show that un-contoured specimens at 0° exhibited the highest load-bearing capacity. For the contoured specimens, the measured K_{IC} values decreased with raster orientation. The 0° orientation exhibited the highest K_{IC}, while the 45° orientation showed a reduction of approximately 20%, and the 90° orientation demonstrated the lowest value, with a decrease of about 33% compared to 0° raster orientation. In contrast, the contoured specimens displayed more scattered results, mainly due to the variability introduced by the pre-cracking process. The 45° orientation exhibited the lowest performance among all orientations, with values approximately 23% lower than the 0° orientation. The 90° orientation also showed reduced performance, with values approximately 18% lower than those at 0°, Figure 1.

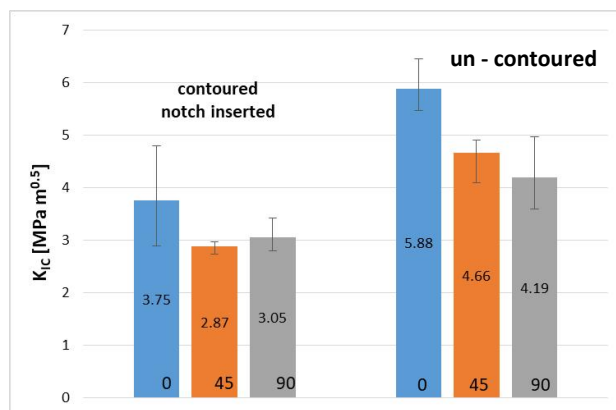


Figure 1. Fracture toughness of PETG

Keywords: Additive manufacture, Fused Deposition Modelling, PETG, Fracture toughness

Acknowledgement

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MICROSTRUCTURE AND PROPERTIES OF METASTABLE HIGH-ENTROPY ALLOYS PREPARED BY SLM TECHNOLOGY

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Abstract

Selective Laser Melting (SLM) is one of the advanced metal additive manufacturing technologies. Metastable high entropy alloys possess excellent ductility and toughness, but its low strength hinders its engineering applications. Therefore, many studies have been carried out to improve the strength of metastable high entropy alloys while maintaining high ductility. In present study, Fe₅₀Mn₃₀Co₁₀Cr₁₀ metastable high entropy alloy powders were used to prepare bulk alloy material by SLM technology. At first, the optimal process parameters for preparing bulk metastable high-entropy alloy by SLM were explored. And then the Si element was added respectively to the metastable high-entropy alloy powders which were used to prepare the bulk alloys by SLM. The effect of Si elements on the microstructure and properties of metastable high-entropy alloys were investigated.

The phase structure of Fe₅₀Mn₃₀Co₁₀Cr₁₀ high-entropy alloy formed by SLM technology is FCC+HCP dual-phase structure. The cross-sectional and longitudinal cross-sectional morphologies are strip-shaped molten pool morphology and "fish scale"-shaped molten pool morphology, respectively. Compared with the as-cast Fe₅₀Mn₃₀Co₁₀Cr₁₀ high-entropy alloy, the SLM-formed alloy has improved tensile strength.

The addition of Si element has a significant effect on the strengthening and toughening of Fe₅₀Mn₃₀Co₁₀Cr₁₀ high-entropy alloy formed by SLM technology. With the increase of Si content, the yield strength and tensile strength gradually increased, and the elongation showed a trend of increasing first and then decreasing. Si element can reduce the stacking fault energy of the alloy, so that the TRIP effect activated in the plastic deformation process of the alloy is more sufficient, and the alloy can be strengthened and toughened under the combined action of dislocation strengthening, solid solution strengthening, TRIP effect and TWIP effect. When the Si element content was 3% (at. %) and 5% (at. %), the tensile strength and elongation were 875.4 MPa, 33.5 % and 956.4 MPa, 29.4 %, respectively.

Keywords: Metastable high-entropy alloy; Additive manufacturing; Selective laser melting

DEVELOPMENT OF COATINGS FOR THE PROTECTION OF METALS STRUCTURES BASED ON PYROPHYLLITE, ZEOLITE AND TALC

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Abstract

The goal of this work is the development of two types of protective coatings based on pyrophyllite and talc and coatings based on pyrophyllite and zeolite. For two types of coatings, a mixture of 80% pyrophyllite, grain size 20 μm and 20% talc, grain size 15 μm , i.e. 80 % pyrophyllite, grain size 20 μm and 20% zeolite, grain size 15 μm , was used as a filler, respectively. In the composition of the coating, the total amount of refractory filler was 85%, binder based on epoxy resin 7-10%, 1-2% organic additives and solvent based on water. Pyrophyllite contributed to the improvement of thermos stability and mechanical resistance of the coating, talc improved the ability to adhere and coat filler grains, while zeolite contributed to the improvement of microporous adsorption of active phases, gases, heat, toxins, heavy metals. The manufacturing technologies of these coatings are ecologically clean. The characterization of the obtained coatings was carried out using the XRD, SEM and ultrasonic vibration method with a stationary sample according to the ASTM G32 standard. Research has shown that the obtained coatings increase the anti-corrosive and thermal protection of metal substrates, and in particular, the resistance to wear and cavitation erosion is increased. This provides wide possibilities of application of these coatings in industry, construction, energy, military industry.

Keywords: protective coatings; pyrophyllite-talc; pyrophyllite-zeolite; improved properties; environmental acceptability

Acknowledgement I

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Acknowledgement II

The authors would like to thank AD Harbi-Sarajevo B&H for providing samples of pyrophyllite for experimental research.

BALANCING WEIGHT AND STRENGTH OF 3D PRINTED PETG AND PLA CANTILEVER BEAMS THROUGH TOPOLOGY OPTIMIZATION

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Abstract

Topology optimization is a computational method used in the design of elements to achieve optimal performance, such as maximizing stiffness and minimizing weight. Therefore, it is considered a potent tool that enables engineers to design elements that are both lightweight and strong. In this study, cantilevers made of thermoplastic materials (PLA and PETG) were analyzed before and after applying topology optimization. Afterwards, the cantilevers were 3D printed. By removing unnecessary mass, the structural integrity is not compromised; instead, a lighter structure is obtained without losing strength. It is a significant challenge when it comes to parts for the aerospace or automotive industry manufactured through 3D printing. A new model shape is obtained, meaning that material is retained in areas where it is most needed to resist stresses, thereby preventing cracks or failure. Therefore, topology optimization provides a prediction of where and how cracks may occur, as well as how they propagate under specific loads. In this study, beams (PLA and PETG) measuring $50 \times 20 \times 8$ mm were analyzed under a load of 100 N applied to the free end. Two scenarios of mass reduction were considered: 50% (factor 0.5) and 70% (factor 0.3), respectively. The initial masses of the base (non-optimized) parts were 10.00 g (PLA) and 10.16 g (PETG), while the deflections after load application were 0.2604 mm and 0.3551 mm for PLA and PETG, respectively. The analysis of both scenarios showed significant weight savings (around 5 g for 50% reduction, and around 3 g for 30% reduction), while the maximum bending stress for 50% and 70% retention amounted to 18.75 MPa and 31.25 MPa, respectively. Although the maximum stress value at 70% is still below the typical tensile strength for both materials, it is essential to consider that the safety factor decreases as the stress increases.

It demonstrated that PLA is more brittle, while PETG is a more rigid material. However, there are still limitations related to the selection of printing parameters and technology. Nevertheless, it is essential to emphasize that topology optimization plays a significant role in reducing manufacturing costs and minimizing environmental impact.

Keywords: Stress analysis; mass reduction; Topology optimization; 3D printing; PETG; PLA

Acknowledgement

This investigation is financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under Contract No.: 451-03-136/2025-03/ 200012. The goal of this work aligns with SDGs (especially SDGs 9 and 2).

ASSESSMENT OF WELDED JOINT INTEGRITY OF ARMOUR STEEL SA 500 BASED ON FRACTURE MECHANICS PARAMETERS

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Abstract

The integrity of welded joints is a key factor in terms of reliability and safety of structures made by armour steels. In this paper, the experimental compliance method according to the ASTM E1820 standard, was used to determine the fracture mechanics parameters and construct resistance curves for the base material, HAZ and weld on welded joint of armour steels SA 500. For welding of armour steel, which belong to ultra-high strength and high hardness steel, austenitic filler material was most often used in order to obtain the best possible impact toughness and avoid preheating. In this paper, a different approach to welding is presented, where a high-strength wire was used as a filler material with optimized welding parameters. The results show that the base material has the lowest values of fracture mechanics parameters, while the degraded zone (HAZ and weld metal) shows elevated values that do not differ so much as to affect the anti-ballistic protection of the weld. Understanding the obtained results enables a more reliable assessment of the integrity of welded joints of armour steels and a more precise assessment of the service life and safety of armoured structures exposed to extreme loads.

Keywords: armour steel; compliance method; K_{JIC} ; J_{IC} ; DIC; resistant curve

INFLUENCE OF GEOMETRIC FACTORS AND PROCESS-INDUCED ATTRIBUTES ON THE MONOTONIC AND FATIGUE BEHAVIOR OF AlSi10Mg TPMS LATTICES: IMPACT OF SCALE, UNIT CELL SIZE AND WALL THICKNESS

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Abstract

Additive Manufacturing (AM) has enabled the fabrication of complex lattice structures, now widely used in biomedical implants, automotive components and aerospace systems. Among the geometric factors influencing structural integrity, scale plays a critical role in encompassing both unit-cell size and wall thickness. Therefore, in order to isolate their individual effects, this study investigates the monotonic and fatigue behavior of uniform sheet-based TPMS gyroid lattices under three conditions: (a) increasing scale, (b) increasing unit-cell size at constant wall thickness, and (c) increasing wall thickness at constant unit-cell size. Key mechanical properties such as relative density, slenderness, and surface-to-volume ratio are discovered to deviate from design due to process-induced inaccuracies, particularly at smaller wall thicknesses. Monotonic properties are primarily governed by slenderness and relative density, with optimal performance achieved at smaller unit-cell sizes and larger wall thicknesses. Fatigue behavior is influenced by both relative density and surface roughness, with the best results occurring under the same geometric conditions. Overall, unit-cell size exerts a stronger influence than wall thickness, as it more consistently yields favorable combinations of mechanical attributes. While scale variation mirrors the trends of unit-cell size, fatigue performance is further shaped by the relationship between deformation behavior and surface quality.

Keywords: Additive Manufacturing; TPMS lattice; Compressive behavior; Fatigue properties

FATIGUE FRACTURE BEHAVIOR OF ADDITIVELY SLM MANUFACTURED TITANIUM ALLOY SUPER STRUCTURES

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Abstract

SLM additively manufactured lattice structures are highly promising for aerospace vehicles due to their excellent weight reduction performance and design flexibility, fulfilling the demand for high-performance, lightweight, and integrated components. However, surface roughness and internal porosity introduced by additive manufacturing tend to serve as initiation sites for fatigue cracks, potentially leading to premature failure of the lattice structures. To investigate effects of surface roughness and porosity on fatigue performance, BCC lattice specimens were designed and fabricated by additive manufacturing. Fatigue tests under five different loading levels were conducted to obtain the corresponding S-N curves. A semi-empirical formula was used to calculate the stress concentration factor introduced by surface roughness. Additionally, the concept of effective load-bearing area was applied to account for the influence of both porosity and surface roughness. The accuracy of this method was verified through finite element simulations based on 3D reconstructed models, and the Neuber-Kuhn formula was used to estimate the fatigue limit. Based on the effective area correction, a fatigue S-N curve for a single strut was established, then a mapping method from the single-strut S-N curve to the lattice S-N curve was developed, and a corrected S-N curve was proposed. It is shown that the model incorporating effective load-bearing area correction more accurately reflects the coupled effect of surface roughness and internal porosity, thereby it can improve the predictive accuracy of the fatigue limit and fatigue life of the lattice structures. The periodic boundary conditions in one unit lattice can be built and effectively simulate stress concentration in the whole structure. The corrected S-N curve is used to predict the fatigue life of the lattice, and its results fall within a scatter band of factor 3.

Keywords: Additive Manufacturing; Superstructure; Surface Roughness; Pore; Fatigue Life

Acknowledgement

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SOLID-STATE NORBORNADIENE PHOTO-THERMAL FILMS FOR EFFICIENT SOLAR ENERGY STORAGE

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Abstract

A solid-state photo-thermal energy storage film based on norbornadiene (NBD) molecules has been developed, which converts solar energy into chemical energy through photoisomerization reactions and releases it as thermal energy upon heating. The optical absorption, energy storage properties, tensile strength and thermal conductivity of the four NBD molecules were evaluated, all of which exhibited excellent energy storage performance and application potential. Among them, the NBD4 film demonstrated the highest thermal storage capacity, reaching up to 202 J g⁻¹. In addition, the influence mechanism of different substituents and polystyrene (PS) concentrations on NBD was analyzed from a microscopic perspective. When integrated with photovoltaic (PV) cells, the solid-state photo-thermal energy storage films absorb ultraviolet (UV) light, lowering the PV cell temperature nearly 5°C while simultaneously storing UV photons as chemical. This results about 3% increase in overall system efficiency. After irradiation, the NBD film is additionally integrated with the thermoelectric generator (TEG). The stored energy is converted into electrical energy, enhancing thermoelectric conversion efficiency. The solid-state film proposed in this study effectively addresses the issues of poor thermal stability and leakage associated with liquid-based systems while remaining fully compatible with existing PV modules, thereby enhancing solar energy storage and heat release efficiency.

Keywords: NBD molecules; Energy storage film; Optical absorption; Photo-thermal conversion

Acknowledgement

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DESIGN AND OPTIMIZATION OF BIOINSPIRED GYROID LATTICES UNDER PURE TORSION

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Abstract

Designing lightweight structures is a key objective across various engineering fields, particularly in aerospace and automotive applications. A promising strategy to achieve this goal is the use of lattice structures: these porous architectures, generated by the periodic repetition of a unit cell, offer an optimal trade-off between weight reduction, mechanical strength, and fatigue resistance.

Among various lattice topologies, the gyroid, a triply periodic minimal surface, has emerged as particularly advantageous due to its smooth, continuous geometry. The absence of sharp junctions reduces stress concentrations, enhancing mechanical robustness, while its inherently self-supporting nature makes it suitable for additive manufacturing processes.

Despite extensive research on gyroid lattices under static loading and mode-I fatigue conditions, their mechanical behaviour under mode-III remains relatively unexplored. Nature, however, offers inspiration for enhancing the torsional response of materials. Biological systems, such as the exoskeletons of mantis shrimp, tree trunks, and bone microstructures, have evolved over centuries, developing highly optimized structures tailored for specific functions. Helicoidal Bouligand structures, observed in arthropod cuticles, demonstrate remarkable resistance to twisting, in addition to remarkable ductility and toughness.

This study aims to translate these biological features into engineered structures and to address the existing gap regarding mode-III behaviour. It focuses on analysing the static torsional response of gyroid lattices arranged according to Bouligand-inspired stacking principles.

Lattice specimens were produced as cylinders composed of concentric layers of gyroid cells. Each layer is rotated concerning the one beneath it, while the wall thickness is radially modulated to keep a constant relative density throughout the volume. The rotation follows a polynomial pattern that mimics the pitch gradient features observed in mantis shrimps' Bouligand architectures. By systematically varying the polynomial coefficients, nine different topologies were generated. A design of experiment (DoE) campaign then identified the best-performing configurations in terms of yield strength under pure torsion. These optimal architectures will underpin future studies on mode-III fatigue behaviour in Bouligand-inspired and other bio-inspired lattice architectures.

Keywords: Gyroid, Lattice; Torsion; Bio-inspired; Bouligand

FATIGUE BEHAVIOR OF MINIATURIZED Ti-6Al-4V LATTICE STRUTS: COMPARING CONTINUOUS AND PULSED WAVE L-PBF

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Abstract

Metal additive manufacturing enables the fabrication of complex lattice architectures with excellent strength-to-weight ratios and tunable mechanical properties, yet concerns over fatigue durability continue to hinder their widespread adoption in critical structural applications. Among available techniques, Laser Powder Bed Fusion (L-PBF) is particularly notable for its ability to tailor microstructure and surface quality through the control of laser emission parameters. While continuous wave (CW) and pulsed wave (PW) strategies have been widely assessed in terms of dimensional accuracy and defect formation, their influence on fatigue performance under industrially relevant processing conditions remains insufficiently explored. Furthermore, the substantial material demand and cost associated with full-lattice fatigue testing often limit large-scale experimental campaigns, restricting insight into the mechanisms driving fatigue failure in lattice components.

To address these limitations, this study investigates miniaturized Ti-6Al-4V strut specimens, designed as representative elements of lattice assemblies, thereby reducing material consumption while enabling systematic evaluation of processing strategy and build orientation effects. Using parameter sets optimized to balance productivity and quality, single struts were fabricated via CW and PW L-PBF in three orientations (90°, 45°, and 15°) relative to the build plate. Fatigue tests at $R = -1$ revealed pronounced differences between CW and PW specimens, demonstrating the combined impact of laser mode and orientation on fatigue life. To clarify these trends, surface morphology analysis, porosity quantification, and electron backscatter diffraction (EBSD) characterization were performed. EBSD revealed that variations in prior β -grain size and morphology played a decisive role in ruling fatigue resistance, consistent with predictions from established crystal plasticity models.

Overall, the findings provide actionable guidance for optimizing L-PBF processing strategies that balance mechanical reliability with economic efficiency, thereby supporting the broader adoption of metallic lattice structures in fatigue-critical engineering applications.

Keywords: Laser-Power Bed Fusion; fatigue analysis; Ti6Al4V; miniaturized specimens; Lattice structures

Acknowledgement

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INFLUENCE OF FIBRE ORIENTATION ON THE REDUCTION OF MECHANICAL PROPERTIES IN INJECTION-MOULDED TEST SPECIMENS

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Abstract

The most important factors influencing the mechanical performance of short fibre-reinforced composites are the material microstructure and the manufacturing process used. Injection moulding induces complex, locally varying fibre concentration and orientation along the flow path of the material as well as through the thickness of the moulded part. This can have a significant impact on the final product, resulting in heterogeneous and anisotropic structural properties, particularly near gates and in the places where materials from different directions meet to form weld lines. Over the past years, several representative theoretical models for predicting fibre orientation have been developed and implemented in commercial injection moulding simulation software. In this study, the iARD-RPR (Improved Anisotropic Rotary Diffusion and Retarding Principal Rate) model integrated within Moldex3D has been used to predict the influence of different gate positions on the local reduction of mechanical properties in injection-moulded test specimens made of glass fibre-reinforced PA6. The changes in the position and shape of the regions with a significant deterioration in fibre orientation are described, as well as changes in the distribution of fibre orientation tensor components at specific locations within these regions. Tensile tests were conducted to relate the differences in stress and strain to the anisotropy present in the test specimens.

Keywords: short fibre-reinforced composites; fibre orientation tensor; injection moulding; Moldex3D simulation

Acknowledgement

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FRACTURE TOUGHNESS ANALYSIS OF A WELDED JOINT ON HIGH-STRENGTH STEEL

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Abstract

Fracture mechanics parameters are used as relevant parameters in structural safety assessments. The paper describes the method of normalization according to the ASTM E1820 standard for directly obtaining J-R and d-R resistance curves from force and CMOD records, together with measurements of the initial and final size of stable crack growth from the fracture surface of the sample. This test method covers procedures and guidelines for determining the fracture toughness of metallic materials using the parameters: JIC, KJIC, and CTOD (δ). The fracture toughness of the welded joint of high-strength steel was analysed experimentally.

Keywords: high-strength steel; fracture mechanics; fracture toughness

EXPERIMENTAL FIELD ANALYSIS OF DAMAGE-FAILURE TRANSITION IN COMPOSITE MATERIAL WITH A STRESS CONCENTRATOR UNDER CYCLIC LOADING (APPLICATION OF DIC AND X-RAY TOMOGRAPHY TECHNIQUES)

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Abstract

The evolution of damage and the transition to failure reveal critical phenomena, as demonstrated by internal variables such as the defect density tensor (characterizing damage-induced strain) and the actual susceptibility parameter (linked to defect spacing, including porosity, microcracks, and microshears). The emergence of collective defect orientation and volume modes drives two distinct criticalities, leading to defect clustering as a precursor to failure.

This study introduces a methodology for analyzing damage evolution in carbon fiber materials under cyclic loading by combining microtomography data with digital image correlation. The analysis identified two distinct damage thresholds, corresponding to matrix cracking and interlaminar delamination, which are detectable as critical strain levels in acoustic emission energy curves. The methodology employed cluster analysis and Bayesian segmentation to quantify pore development using order parameters like volume and surface area. The results show that cyclic loading promotes pore expansion and coalescence, significantly reducing specimen strength. While the overall pore orientation distribution remains consistent, their clustering behavior changes, forming two distinct groups: one randomly oriented and another with transverse alignment. The proximity of pores emerged as a critical factor, increasing the probability of their merger into larger defects like delaminations and cracks.

Strain distributions at the most intense deformation sites form compact clusters that reflect the hyperbolic stress field near a crack tip, consistent with Irwin's singular solution. This points to the emergence of collective effects and critical phenomena driven by the collective orientation and volume of defects, which act as a precursor to macro-failure. The work successfully establishes a correlation between microstructural parameters, such as pore anisogeometry and clustering, and fracture mechanics criteria. These insights link integral structural characteristics to specific damage progression stages, advancing the development of more accurate predictive models for composite material failure

Keywords: Composites; Carbon fiber material; Defects; Damage; Microtomography; DIC

Acknowledgement

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FABRICATION OF MULTI-MATERIAL STRUCTURES FROM AUSTENITIC TO FERRITIC STAINLESS STEELS VIA DUAL-WIRE ARC ADDITIVE MANUFACTURING

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Abstract

In the context of carbon neutrality, the Ni-free ferritic stainless steel (FSS) has regained the spotlight as a potential substitute of austenitic stainless steel (ASS) for its lower cost. Moreover, owing to its good thermal conductivity and superior resistance to stress corrosion cracking (SCC), the bimetallic joining of FSS-ASS is widely used in industrial applications such as petrochemical power plants, energy conversion systems and nuclear reactors. However, the differences of chemical, physical, mechanical, and metallurgical properties make dissimilar metal welding (DMW) intrinsically more difficult as compared to similar metal welding. Functionally graded materials (FGMs) are advantageous in mitigating this challenge because their chemical composition changes gradually from one side to the other, resulting in continuous or quasi-continuous gradient changes in properties according to the design requirements. In the past decade, the emerging additive manufacturing (AM) technologies are acknowledged as a promising approach to fabricate FGMs in current industrial applications, featured as flexible geometry, cost optimization as well as higher productivity. Among them, wire-arc additive manufacturing (WAAM) process utilizes an electric arc as the heat source to melt metal wires and deposit components layer by layer, which provides a combination of high deposition efficiency, low device and material cost, and unlimited building size.

In this work, the ASS-FSS bimetallic components with different compositional gradient design were fabricated by GTAW-based WAAM process. The corresponding residual stress and temperature field distribution during deposition process were numerically simulated by finite element model (FEM) using ABAQUS software. Then, with the assistance of temperature field simulation, the microstructural evolution mechanism was comprehensively revealed. Subsequently, the mechanical properties of as-deposited components were assessed via hardness tests, impact tests and tensile tests, and the corresponding deformation and fracture behaviors were also comprehensively investigated. As a consequence, the manipulation of retained austenite (RA) in stainless steel was realized by fabricating FGMs, which effectively improved the mechanical properties of ASS-FSS joints. This study provides a good inspiration for the optimization on microstructure and properties of multi-material structures through compositional gradients design.

Keywords: Multi-material structure; Functionally graded materials (FGMs); Wire-arc additive manufacturing (WAAM); Microstructural evolution; Mechanical properties

Acknowledgement

This work was supported by Tohoku University NEXUS Postdoctoral Research Fellow Program.

STRUCTURAL MODIFICATION OF THE CARGO HOLD DOUBLE BOTTOM FOR A MULTI-PURPOSE VESSEL

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Abstract

Increasingly, modern maritime vessels must demonstrate structural flexibility to accommodate the growing need for transporting various cargo types in response to evolving industry demands. As a result, regulatory bodies, and their respective rules, regulations and standards, require that novel structural solutions are to be verified through advanced structural assessments, including finite element analysis (FEA). Therefore, this study focuses on FEA-based structural assessment and optimization of the double bottom and underdeck reinforcement structure in the two cargo holds of a multi-purpose vessel originally designed for bulk cargo. However, the vessel now also needs to carry standard 20-foot high cube containers, imposing a significantly different loading scenario. While bulk cargo results in nearly uniform load distribution, containerized cargo introduces concentrated point loads. The analysis accounted for container weights, gravity, and accelerations due to ship motion. Von Mises stress criteria were used to evaluate the structural response, according to the rules and regulations of two major regulatory bodies: Lloyd's Register and International Association of Classification Societies. The results indicated that the original structure could not withstand the new loading demands according to the regulatory standards. Consequently, structural modifications were proposed and implemented. The study highlights that even multi-purpose vessels, which are assumed to be suitable for various cargo types by design, require structural modifications to safely accommodate containerized cargo. The presented solution demonstrates how targeted reinforcements can ensure compliance with modern classification society rules while enabling operational flexibility.

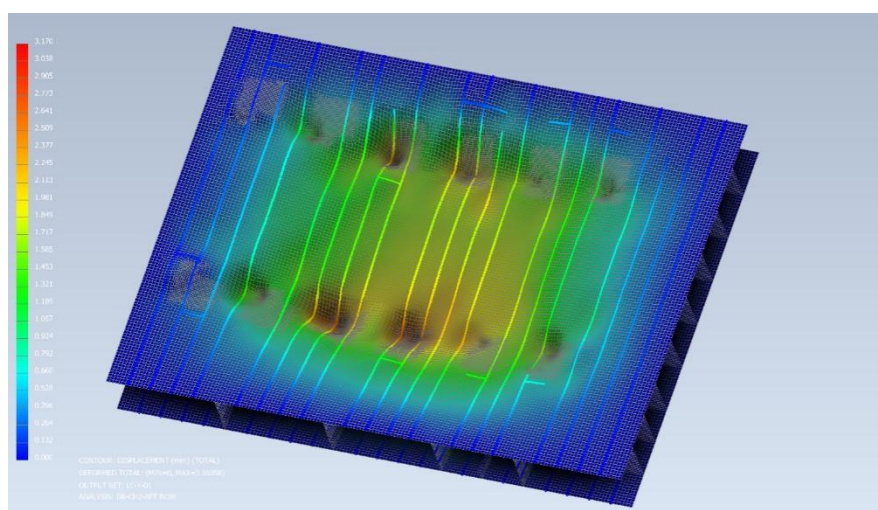


Figure 1. Cargo holds no. 2 (aft part) – displacement results for one loading case.

Keywords: FEA; multi-purpose vessel; ship motions; container load

QUANTIFICATION OF DEFECTS IN FIBRE REINFORCED COMPOSITES BASED ON AN XCT IMAGE

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Abstract

Fiber-reinforced composites are hierarchical materials with a particular microstructure at the micro-(fibres organized into yarns, plies, or random mats within a matrix) and mesoscale (plies organized into laminates, yarns organized into a textile reinforcement).

The design is assisted with quantifying the XCT-visualized features (Figure 1) and linking these features with the mechanical and functional performance. XCT opens two routes for this:

- Quantification of the microstructure, of the manufacturing defects and in-service damage. Examples of such quantification are fibre orientation distribution, size, shape, and spatial distribution of voids, matrix cracks, or fibre break density. The quantification results can be used for assigning local properties in FE models or serve as the basis for global performance predictions
- Creation of a “digital twin” of the material, which reproduces the geometry of microstructural elements and defects with maximum possible precision; the XCT spatial resolution is among the factors limiting this precision.

The talk is mainly based on the research conducted in the Department of Materials Engineering, KU Leuven, in collaboration with other groups worldwide, summarised in the book chapter:

Quantifying tomographic images of fiber-reinforced composites

S.V. Lomov, S. AhmadvashAghbash, Ch. Breite, R. Guo, R. Karamov, M. Mehdikhani, J. Soete, I. Straumit, S. Upadhyay, Y. Zhao, M. Wevers, Y. Swolfs

In: Visualisation in industrial X-ray computed tomography, eds. Ch. Heinzl, T. Sauer, N. Uhlmann. Springer, to appear in 2025

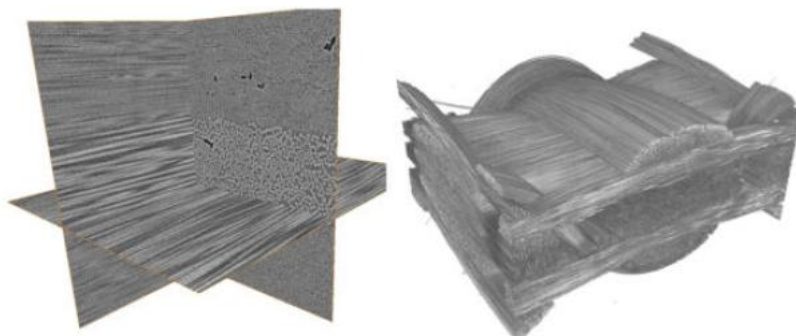


Figure 1. XCT images of a composite hybrid laminate and a 3D woven composite reinforcement

Keywords: X-Ray micro-computed tomography; fibre reinforced composites; effect of defects

FATIGUE BEHAVIOUR OF FDM-PRINTED ORTHOPAEDIC PLATES WITH VARYING INFILL DENSITIES

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Abstract

Orthopaedic plates are well-established medical devices conventionally manufactured from metals, most commonly titanium alloys. However, Additive Manufacturing (AM) introduces new possibilities by enabling complex internal geometries with tailored infill patterns and densities. Additionally, there is a growing trend in biomedical applications towards biodegradable materials, such as PLA (Polylactic Acid), which naturally degrade after fulfilling their function. This eliminates the need for secondary surgeries to remove implants, providing clear benefits for both patients and healthcare systems. In orthopaedic applications, such materials allow plates to gradually degrade once the bone has healed. Moreover, optimising the internal structure of orthopaedic plates can improve mechanical performance, promote bone healing, and facilitate drug delivery applications.

This study builds upon prior research by our group at the University of Belgrade, focusing on the best-performing orthopaedic plate design. Numerical models incorporating honeycomb infill structures with densities ranging from 10% to 100% were developed to evaluate structural integrity under fatigue loading. Fatigue crack growth was modelled using the SMART method in ANSYS Mechanical (ANSYS Inc., Canonsburg, PA, USA), employing a four-point bending setup, as per the ASTM F382 standard. A validated PLA material model was applied, and the results were subsequently compared with existing data on conventionally manufactured titanium plates to evaluate performance.

Keywords: Orthopaedic plates; Additive manufacturing; FDM; Infill density; PLA material

Acknowledgement

Authors acknowledge the support from the Ministry of Science, Technological Development, and Innovations (Republic of Serbia), contract No. 451-03-136/2025-03/200213 (from February 4, 2025).

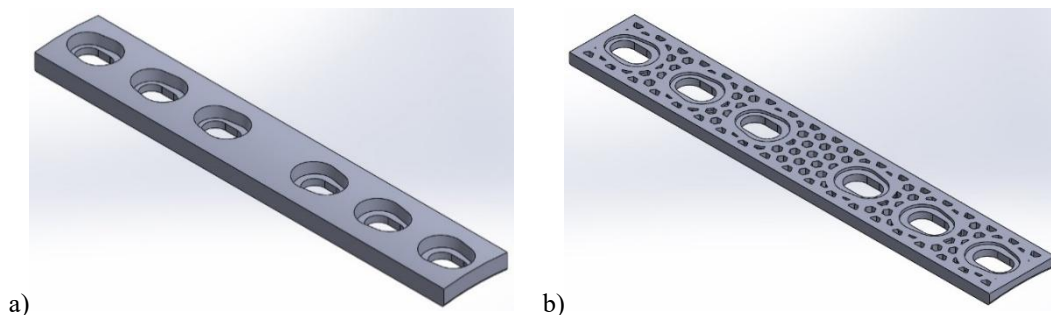


Figure 1. a) Orthopaedic plate design; b) Honeycomb infill structure layout.

EXAMINATION OF FRACTURE RESISTANCE OF POLYMER MATERIALS USING NEW RING TENSILE SPECIMENS

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Abstract

This study deals with the development and application of new Pipe Ring Notched Tension (PRNT) specimen geometry for assessing fracture resistance in polymer materials. The aim of the research was to provide a comparative analysis of fracture behavior characterization in thin-walled specimens, particularly pipe segments manufactured using additive technologies. Two types of materials were tested: PLA (polylactide acid), produced using the FDM (Fused Deposition Modeling) technique, and PA12 (polyamide), produced using the SLS (Selective Laser Sintering) technique. Mechanical testing was carried out using a universal testing machine, with Digital Image Correlation (DIC) applied for precise measurement of deformation and crack propagation. Fracture parameters such as CMOD (Crack Mouth Opening Displacement) and CTOD (Crack Tip Opening Displacement) were determined and compared for both manufacturing techniques. The PRNT specimens with a notch ratio of $a_0/W = 0.5$, produced using the FDM technique, exhibited approximately seven times lower maximum CTOD value compared to SLS specimens. This result confirms the pronounced brittleness of PLA in cylindrical geometry, making it impossible to construct a crack growth resistance curve for this material under the given conditions. The study confirms the applicability of PRNT specimens for fracture analysis in polymers and highlights the advantages of the SLS technique in achieving higher fracture resistance and improved measurement accuracy. The obtained results provide a foundation for further research and the standardization of non-traditional testing methods for polymer and metallic pipes.

Keywords: Pipe Ring Notched Tension (PRNT) specimens; Digital Image Correlation – DIC; Crack Mouth Opening Displacement - CMOD; Crack Tip Opening Displacement - CTOD

Acknowledgement

This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (contr. 451-03-136/2025-03/200213 and 451-03-136/2025-03/200135). This research was also supported by Western Balkans Mobility Scheme (grant: WBMS-047).

OPTIMIZED BILATERAL SURFACE ULTRASONIC ROLLING TECHNOLOGY ASSISTING DIRECTED ENERGY DEPOSITION OF THIN-WALLED MEDIUM-ENTROPY ALLOY WITH HIGH MECHANICAL PERFORMANCE

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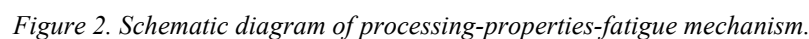
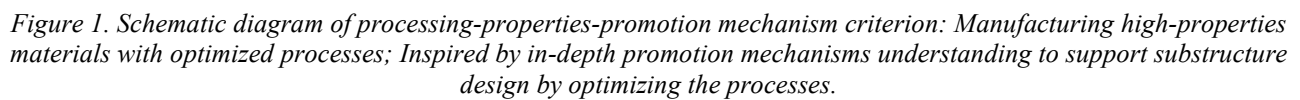
Abstract

Laser directed energy deposition (DED) offers significant advantages for the integral manufacturing of large-scaled thin-walled workpieces. Nevertheless, how to improve the yield strength (YS) and fatigue properties of thin-walled parts fabricated by DED is a crucial issue. As an advanced surface strengthening technology, surface ultrasonic rolling technology (USRP) is aimed to improve the mechanical performances of additively manufactured workpieces. In this work, an optimized bilateral USRP parameter (including the load, repeated times, scanning speed, etc.) with high manufacturing efficiency and surface integrity was developed to fabricate thin-walled CoCrNi medium-entropy alloy (MEA) parts (~1.5 mm thickness). Compared to the as-deposited sample, the sample treated by USRP shows a good strength-ductility balance (ultra-high YS and ductility with 1026.6 MPa and 21.9%, respectively), as well as an impressive improvement in the high-cycle fatigue limit strength of 76.9%. Through multi-scale characterization and calculation, the reasons for high mechanical performance were uncovered that the ultra-high strength is predominantly attributed to the high-density pre-existing dislocations and deformation twins (DTs); Good ductility is related with high hetero-deformation induced stress and the activation of multiple deformation substructures induced by high flow stress, such as dislocations, DTs and hexagonal close-packed phase. Further, the improvement in fatigue performance is ascribed to the closure of manufacturing defects in the surface or subsurface and inhibited surface roughening behavior from stable gradient nanotwinned layer. Finally, the work reveals the quantitative relationship among processing-properties-promotion mechanism (PPP), which provides a criterion to meet the specific mechanical performance of DEDed thin-walled components by precisely tuning the bilateral USRP parameters.

Keywords: Directed energy deposition; Optimized bilateral USRP; Gradient nanotwinned substructure; Strength-ductility balance; Fatigue behavior

Acknowledgement

This work was financially supported by the National Key Research and Development Project (Grant No. 2022YFB4602100), National Natural Science Foundation of China (Grant No. 52205152, No. U21B2077, and No. 52275147). Binhan Sun acknowledges the financial support from the Science Center for gas turbine project from China (Project No. P2022-C-III-002-001).



THE EFFECT OF PRE-STRAIN ON THE STRENGTH OF SELECTIVE LASER MELTED (SLM) INCONEL 718

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Abstract

The dominant advantage of additive manufacturing, also referred to as 3D printing, is its flexibility in allowing fabrication of complex geometries with minimum waste of material. However, Metal Additive Manufacturing (MAM) techniques also face challenges that need to be identified and addressed effectively. Inconel 718 is a high strength material widely used under extreme working conditions across the industries. Additively manufactured components made of this material exhibit notably lower strength compared with other manufacturing processes such as forging and hence, post-manufacturing mechanical treatment as a candidate process with the potential to enhance its strength was investigated in this study. The effects of compressive pre-straining on mechanical properties and microstructure of Selective Laser Melted (SLM) Inconel 718 was explored through an extensive experimental study.

Room temperature pre-straining, representative of cold-work manufacturing process, was therefore deployed to explore its potential for enhancement of mechanical properties leading to improved structural integrity. The experimental investigation included a range of tension and compression tests in which the pre-strained specimens were loaded until failure or fracture, along with hardness tests and microstructural analysis. All tests were planned and performed at room temperature on the laboratory scale specimens that were fabricated by SLM technique.

The tensile yield and ultimate strength of samples with and without certain levels of pre-straining were measured for all specimens. Collated experimental data allowed comparison of strengths of as received with pre-strained specimens. The findings were used to interpret and understand the effect of pre-straining and explore how far it could improve the integrity of the components made using this additive manufacturing technique. Inducing 30 % pre-strain to SLM specimens increased the tensile yield and ultimate strengths by more than 30 % and 10%, respectively. Interestingly, the compressive yield strength after 30 % pre-strain increased massively, by around 80 %.

The change in grain size of samples was also measured following the forementioned levels of induced pre-strain to understand the link between the grain size and the change in strength. The average grain size after 30 % pre-strain increased. Additionally, Brinell hardness tests were carried out to provide a more in-depth insight into the study. Brinell hardness following 5 % and 15 % pre-straining reduced. However, 30 % pre-strain increased the hardness compared to the as-received specimens.

Overall, the results revealed that a hybrid fabrication approach by including pre-straining enhances the material strength that in turn improves structural integrity of Inconel 718 SLM components under extreme service conditions.

Keywords: Inconel 718; Selective Laser Melting (SLM); pre-straining; mechanical properties, structural integrity

INFLUENCE OF END GEOMETRY AND DEFECTS ON STRUCTURAL INTEGRITY OF A LIGHT-WEIGHT COMPOSITE STRUT

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Abstract

Design of light weight structures that can perform under extreme loading and environmental conditions with high reliability is crucial for space applications. Hollow struts fabricated with composite materials are a promising option in this regard and have attracted significant research interest in both manufacturing technology and their potential applications. Failure behaviour of composite struts must be well understood before widespread industrial usage. This study presents an investigation on the impact of the geometrical features of near end shape (to facilitate connections to other structural components) on the failure behaviour and load carrying capability under compressive loading where buckling is likely to limit the load bearing capacity of the struts. To understand the failure mechanism and the expected failure loads, the study covered both experimental testing and computational modelling. The study was also extended to explore the damage tolerance capability of struts by including test articles with initial flaws before subjecting to compressive loading. This examination provided grounds to assess the influence of initial damage on the structural response. A strut carefully fabricated to minimize the possibility of initial flaws confirmed by examination was used as the reference. Two other struts with initial flaws were also tested. In all tests the same loading conditions were set. This was a constant low-rate displacement-controlled loading replicating quasi static compressive loading conditions. To obtain a full picture of the response of struts during loading, a combination of strain gauges and digital image correlation (DIC) were placed on the struts to measure deformation and strain field at the locations of particular interest. A finite element model was also developed in which Hashin's failure criterion was incorporated. The finite element model, generated and analysed in ABAQUS, proved to be a fair representative of the experimental set up and good agreement between the experimental findings and finite element results were obtained for strain distribution, failure modes, and failure loads. It was found that the geometry and dimension of the transition zones at both ends of the strut determine the failure location and load carrying capability. Moreover, the presence of small initial flaws hardly affected the structural response.

Keywords: composite struts; failure analysis; Hashin's failure criterion; DIC; finite element analysis

Acknowledgement

The authors would like to thank the European Space Agency (ESA) and the National Physical Laboratory (NPL) for funding this study, and Space Structures GmbH for providing the test articles.

INFLUENCE OF HEAT TREATMENT ON HYDROGEN-INDUCED CRACKING SUSCEPTIBILITY OF API 5L X60 PIPELINE STEEL EVALUATED IN ACCORDANCE WITH NACE TM0284 STANDARD

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Abstract

Hydrogen-induced cracking (HIC) remains a major degradation mechanism affecting the long-term reliability of pipeline steels in sour environments. This work examines the effect of post-fabrication heat treatment on the HIC susceptibility of API 5L X60 steel using the NACE TM0284 standard. The study aimed to determine how controlled thermal treatment can relieve residual stresses and modify microstructural features that influence hydrogen diffusion and trapping behavior.

Steel samples in the as-received condition and those heat-treated at 500°C, 550°C, and 600°C were immersed in a simulated sour solution under controlled conditions. After exposure, the specimens were sectioned and examined for crack morphology, crack length ratio (CLR), crack thickness ratio (CTR), and crack sensitivity ratio (CSR) as prescribed by the NACE TM0284 procedure. Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) analyses were used to assess microstructural evolution, fracture characteristics, and elemental distribution in the cracked regions.

Results revealed that heat treatment effectively reduced the extent of HIC by relieving internal residual stress and promoting microstructural homogenization. The heat treatment conditions provided optimum balance between microstructural stability and hydrogen damage resistance, which led to the lowest measured CLR and CTR values. These findings highlight the potential of controlled thermal treatment as a practical mitigation approach for enhancing the structural integrity of pipeline steels in hydrogen-containing service environments.

Keywords: Hydrogen-induced cracking; API 5L X60 steel; NACE TM0284; Heat treatment; Structural integrity

Acknowledgement

The authors acknowledge the support provided by the Interdisciplinary Research Center for Advanced Materials (IRC-AM) at King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia, under the research grant# INAM2406 for conducting this research work. The authors also appreciate the support of Saudi Aramco and the global pipe company in facilitating the research activities.

FRACTURE BEHAVIOR PIPE-RING SPECIMENS FOR FRACTURE TOUGHNESS TESTING OF THIN-WALLED PIPELINES

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Abstract

Structural integrity assessment of the pipelines requires fracture toughness in order to predict the loading capacity of pipeline or resistance to the initiation and crack growth. The thin-walled structures as pipelines are usually unsuitable for the standard testing of fracture toughness. Particularly, it is very difficult to perform the fracture toughness testing in the case of longitudinal surface cracks. To find an alternative technique for the measurement of fracture toughness of the already delivered pipeline segment, the pipe-ring notched bend specimen (PRNB) has been proposed. In this paper the differences in fracture behavior between the standard single edge notch bending (SENB) and non-standard pipe-ring notched bend (PRNB) specimens are discussed. To avoid the uneven fatigue crack front because of complex fatigue loading which caused different fracture behavior, the standard single edge notched bend (SENB) specimens has been used for comparison to ring specimens. The fracture toughness was measured by testing both types of specimens. The critical crack tip opening displacement was determined as a crack tip surface strain-relaxation by using stereo-optical grading method and compliance method. The comparison between CTOD-R curves of both standard and non-standard specimens shows comparable similarity in fracture behavior, especially in the stable crack initiation, but shows significant difference during ductile tearing.

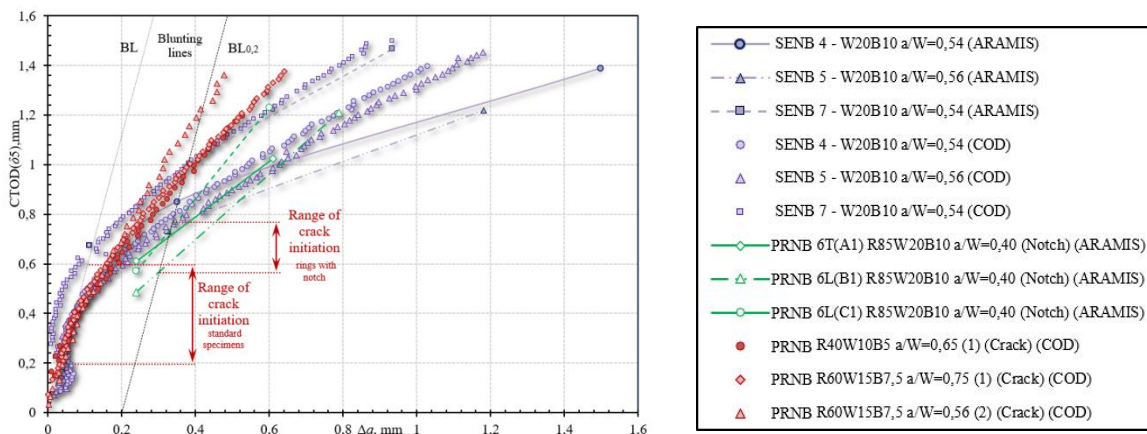


Figure 1. Comparison of the CTOD-R resistance curves between rings and standard specimens

Key words: Pipe-ring specimens, Fracture toughness, Bending specimens, CTOD-R curves

Acknowledgement

The authors would like to acknowledge the EU Research Project (NPOO.C3.2.R3-I1.04.0117) financed from The Recovery and Resilience Facility (NextGenerationEU).

ANALYTICAL AND NUMERICAL STRESS ANALYSIS ON RING SPECIMENS FOR FRACTURE TOUGHNESS TESTING

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Abstract

This paper presents an analytical and numerical investigation of the recently proposed Pipe Ring Notched Bend (PRNB) specimen, designed for fracture toughness testing of pipe materials. The PRNB specimen offers a practical alternative to standard fracture specimens (SENB, CT), particularly in cases where conventional geometries cannot be extracted from pipe walls, such as in thin-walled pipelines. Due to its specific ring-shaped geometry and three-point bending loading configuration, the PRNB specimen exhibits a torsional stress component in the vicinity of the crack, which significantly influences its fracture behavior. The study includes a detailed stress analysis in critical cross-sections of the specimen, combining bending, shear, and torsional effects, Figure 1. Analytical expressions for equivalent stress based on the von Mises criterion are derived and validated through finite element simulations. A comparison between analytically and numerically obtained stress values confirms the reliability of the proposed model in the linear-elastic regime. The results demonstrate that torsional effects must be considered to accurately assess the fracture response of PRNB specimens, especially when evaluating fracture toughness in real pipe applications.

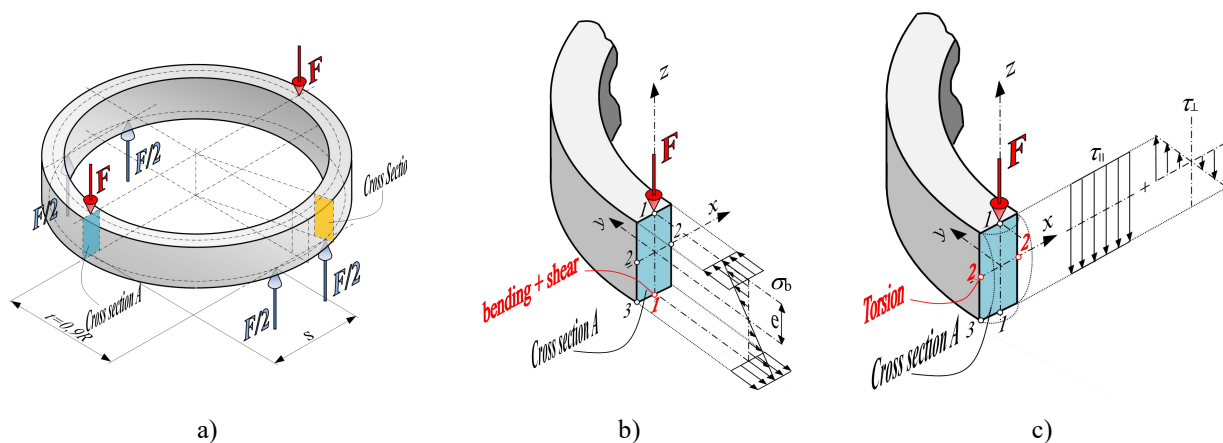


Figure 1. PRNB test specimen: a) PRNB static model, b) bending stress scheme, c) tangential and torsional stress scheme

Keywords: Pipe Ring Notched Bend specimen; PRNB; fracture toughness; pipe

Acknowledgement

The authors would like to acknowledge the EU Research Project (NPOO.C3.2.R3-I1.04.0117) financed from The Recovery and Resilience Facility (NextGenerationEU).

EXPERIMENTAL AND SIMULATION STUDY ON FRACTURE TOUGHNESS OF FIBER-REINFORCED COMPOSITES

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Abstract

Precisely elucidating the influence of various orientations on the fracture behavior of fiber-reinforced composites (FRCs) is crucial for evaluating the structural integrity of defect FRCs. Existing studies lack in-depth analysis of failure mechanisms and accurate prediction of fracture toughness for different orientations. This study investigated the variation of fracture toughness with material orientation through eccentrically-loaded single edge crack tension fracture tests. The digital image correlation and scanning electron microscope techniques were used to reveal the deformation and failure mechanisms during the fracture process. Then, a new I-II mixed mode trilinear cohesive zone model (CZM) subroutine has been developed and used to predict fracture behavior under different orientations. It was found that increasing the orientation angle leads to a higher initiation fracture toughness. Moreover, combined with SEM results, it can be observed that as the orientation angle increases, the failure mechanism shifts from fiber-matrix interface debonding, matrix cracking and fiber bridging to matrix shear failure, fiber breakage and pull-out. Finally, the proposed CZM method can accurately predict fracture toughness under any orientations, and the maximum error is less than 3%. The current research on the damage mechanism and reliability evaluation of FRCs is of great significance.

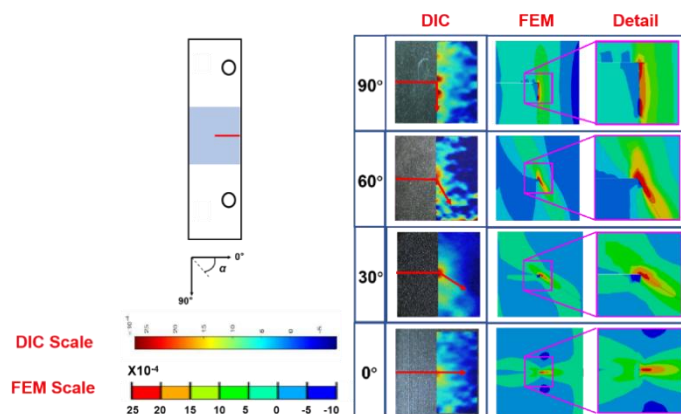


Figure 1. Comparison of the experimental and DIC strain field contour plots.

Keywords: Fracture toughness; Damage mechanism; Composite; CZM; Prediction

Acknowledgement

Support from the National Natural Science Foundation of China (No. 12202305) and the Tianjin Natural Science Foundation (No. 23JCQNJC01910) is gratefully acknowledged.

STRESS CONCENTRATION OPTIMIZATION FOR FUNCTIONALLY GRADED PLATES WITH A PAIR OF CIRCULAR HOLES

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Abstract

Generally, holes and cutouts are introduced to plates not only to meet lightweight demands, but most importantly to serve utility requirements for purpose of service. While the plate is under loading, however, the presence of these holes affect the stress, thus leading to inevitable stress concentrations. Advances in manufacturing technology are allowing to obtain materials with spatially varying mechanical properties, widely known as functionally graded materials (FGMs), offering promising solutions to ameliorate the integrity of structures. The literature provides considerable number of research works that investigate the effect of material gradation on the stress concentration factor (SCF) in plates. Nevertheless, most of studies prefix the spatial variation of the elastic properties by means of prescribed laws endowed with certain parameters, and the reduction of SCF is achieved via the search for the tuning values of these parameters. Should this approach can successfully yield enhanced stress fields in terms of lower SCF at the boundary of the hole, we believe that the establishment of a strategy of searching for the mechanical properties along spatial directions rather than tuning the above parameters is required to fully exploit the inhomogeneity concept associated with FGMs.

In the light of the above strategy, we recently considered a functionally graded infinite plate with a circular hole and subjected to uniaxial traction. Under the assumption of radially varying Young's modulus, an associated structural optimization problem has been formulated and solved with the aid of finite difference method. More specifically, it was shown that if the Young's modulus obeys a sigmoid-like function, the material inhomogeneity is capable of making the stress concentration vanish throughout the radial direction. This peculiar result encouraged us to consider cutouts of different shapes such as elliptic holes, rectangular slots with semicircular ends and circular holes with opposite semicircular lobes, and optimal Young's modulus variations led to elastic performance that outperforms counterparts made of homogeneous and FGMs with commonly employed prefixed gradation laws by far. In the wake of our previous works, we believe it is time to apply this strategy to minimize the stress concentration in plates with a pair of circular holes. The two holes and the adjacent neighborhood are represented by concentric circular strips and the best Young's modulus variations around the two holes is numerically determined in each strip. Numerical optimal solutions are described in graphical forms and comparisons with results from the literature are reported for situations in which plates are endowed with FGM layers around the holes as well as when they are entirely graded.

Keywords: Stress concentration minimization; functionally graded materials; structural integrity; plates with holes; optimization.

HYDROGEN-INDUCED CHANGES IN MECHANICAL PROPERTIES AND FATIGUE LIFE OF ADDITIVELY MANUFACTURED STAINLESS STEELS

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Abstract

The growing adoption of hydrogen as a clean energy carrier introduces material challenges related to structural integrity, particularly hydrogen embrittlement (HE). While HE mechanisms are well understood in conventionally produced steels, the distinct microstructures of additively manufactured (AM) materials—characterized by residual stresses, porosity, and anisotropy—may alter their susceptibility to hydrogen-assisted degradation.

This study compares the influence of hydrogen charging on the mechanical and fatigue behavior of conventionally produced and AM (laser powder bed fusion) austenitic stainless steel AISI 304 and martensitic stainless steel AISI 420. Specimens were cathodically charged with hydrogen (20 mA/cm²) and tested for tensile, impact toughness, surface hardness and fatigue properties. Fracture surfaces were analyzed using Scanning Electron Microscopy to identify hydrogen-related damage mechanisms.

Results show that AM steels exhibit higher strength and hardness but suffer greater fatigue degradation after hydrogen charging. Ductility and tensile strength decrease, while impact toughness remains largely unaffected. SEM analysis revealed hydrogen-assisted crack initiation and propagation.

Overall, additive manufacturing enhances baseline performance yet increases vulnerability to hydrogen-induced damage, emphasizing the need for tailored processing and mitigation strategies to ensure the structural integrity of AM stainless steels in hydrogen environments.

Keywords: Additive manufacturing (AM); Hydrogen embrittlement; Fatigue performance; Mechanical properties; Stainless steel, Fracture analysis

Acknowledgement

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INFLUENCE OF LAYER HEIGHT ON CAVITATION RATE OF 3D-PRINTED PLA

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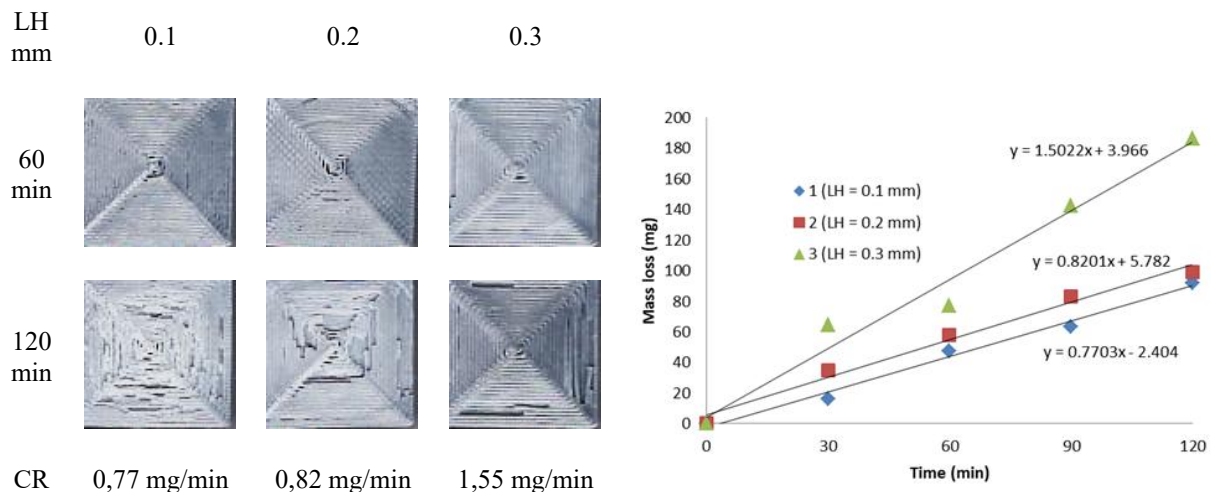
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Abstract

This study investigates the cavitation erosion behaviour of PLA (polylactic acid) specimens fabricated by Fused Deposition Modelling (FDM) using different layer heights (0.1, 0.2, and 0.3 mm). The samples were exposed to cavitation at a frequency of 20 ± 0.5 kHz for 60 and 120 minutes. Visual inspection revealed that smaller layer heights resulted in finer surface morphology, better interlayer bonding, and improved resistance to cavitation. After 60 minutes, slight surface roughening and local delamination were observed in all samples, while after 120 minutes, surface degradation became more pronounced, especially for larger layer heights. Samples printed with a 0.1 mm layer height mainly exhibited plastic deformation and minor delamination, those with 0.2 mm showed a combination of plastic deformation and delamination, whereas the 0.3 mm specimens were dominated by large-scale detachment and severe surface damage. The cavitation rate diagram, obtained from mass loss measurements, confirmed these observations. The lowest mass loss rate (0.77 mg/min) was recorded for the 0.1 mm samples, while the highest rate (1.50 mg/min) corresponded to the 0.3 mm samples. The results demonstrate that increasing layer height significantly reduces the cavitation resistance of FDM-printed PLA due to weaker interlayer cohesion and higher surface roughness.



Keywords: cavitation erosion; 3D printing; FDM; PLA; layer height, mass loss, cavitation rate

Acknowledgement

This work was supported by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia (451-03-137/2025-03/200105, 451-03-136/2025-03/200135, 451-03-136/2025-03/200287) and by COST Action CA23155 – A pan-European network of Ocean Tribology (OTC).

AI-DRIVEN OPTIMIZATION OF 3D-PRINTED SHORT CARBON FIBER-REINFORCED COMPOSITE GRID STRUCTURES

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Abstract

Achieving lightweight, high-stiffness and high-strength has always been a primary objective in the design of composite structures. This study presents an AI-driven optimization framework for 3D-printed short carbon fiber-reinforced composite grid structures. Five basic configurations were designed and tested under three-point bending. Then, a small sample dataset constructed by employing finite element analysis (FEA) was used to train an XGBoost machine learning (ML) surrogate model for predicting specific stiffness and specific strength of the 3D-printed composite grid structures. Meanwhile, the influence of the minimum pore size, X-axis gradient, and Z-axis draft angle on the mechanical performance of 3D-printed composite grid structures was investigated by utilizing the surrogate model. The trained XGBoost model was introduced to develop the multi-objective fitness functions for Non-dominated Sorting Genetic Algorithm II (NSGA-II) to optimize the structural parameters. Finally, prototypes selected from the Pareto front were fabricated and tested in three-point bending. The experimental results demonstrated that the AI-driven optimization led to a 17.40 % weight reduction, while stiffness-to-mass and strength-to-mass ratios are improved by 8.11 % and 21.75 %, respectively. The results show that coupling ML surrogate model with optimization algorithm can significantly improve the design of 3D-printed short-fiber composite grid structures.

Keywords: Machine Learning; Additive Manufacturing; Multi-Objective Optimization; XGBoost; Carbon Fibers

Acknowledgement

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EXPLOSIVELY WELDED STEEL BI-LAYERS INTERFACIAL INTEGRITY AND CAVITATION EROSION RESISTANCE

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Abstract

This study investigates the cavitation erosion resistance and structural integrity of explosively welded steel plates. Structural steel and tool steel were selected to form bi-layer plates, as a combination of strength and toughness desirable in advanced structural applications. Explosion welding was employed to join the two dissimilar steels, with the objective to gain insight into how variations in explosive charge mass influence the bonding integrity, microstructural properties of the joint, and resistance to cavitation-induced damage. The plates were joined in a parallel configuration using "Demex" explosive, which is based on ammonium nitrate and trinitrotoluene, with a small amount of inert additives. Cross-sectional microstructural analyses of the welded joints were performed using stereo and optical microscopy to evaluate the interfacial morphology, bonding characteristics, and potential defects. Cavitation erosion behavior was examined through ultrasonic vibration testing in distilled water with a stationary specimen: cross-section of the joint bi-layer plate. Progressive surface degradation was monitored through periodic mass loss measurements to generate mass loss curves and optical microscopy of the eroded surfaces.

Surface damage on both the base and welded zones was monitored and characterized by optical microscopy to observe the mechanisms of erosion and their correlation with welding parameters. The interfacial zone exhibited characteristic wavy patterns and localized plastic deformation, whose amplitude and continuity increased with higher explosive charge mass, indicating improved metallurgical bonding. The results showed that specimens fabricated using a higher mass of explosive during the welding procedure have improved metallurgical bond quality, better cohesion at the interface, and greater resistance to cavitation erosion. Overall, the findings suggest that optimizing the explosive charge parameters can affect the interfacial microstructure and improve the functional durability of explosively welded joints, which is important for the long-term reliability of multilayered metal plates operating in aggressive, cavitating environments.

Keywords: explosion welding; tool/construction steel; Demex explosive; cavitation erosion

Acknowledgement

This research has been supported by the Ministry of Science, Technological Development and Innovation of Republic of Serbia - contracts No. 451-03-137/2025-03/200325, 451-03-136/2025-03/200026, and University of Defense, Military Academy, Proj. No. VA-TT/1/22-24.

THE EFFECT OF NATURAL AGING ON THE TENSILE PROPERTIES OF PETG-CF FILAMENT

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Abstract

Parts manufactured using additive technology have been an excellent choice for prototyping for some time now. Certain materials, such as PETG, have shown a degree of similarity to metallic materials in terms of relationship between mechanical properties. These materials have demonstrated significant plasticity and toughness in the filaments, as well as the ability to form a "neck" during tensile testing.

Considering all of the above, the question arises as to whether PETG-CF can be used for manufacturing structural elements for smaller loads. In addition to standard tests, which have been performed many times, the question of aging has also emerged, i.e., the degradation of the mechanical properties of manufactured parts after a certain period.

This paper analyzes the change in strength between new samples and samples manufactured 10 months ago from the same PETG-CF filament.

Keywords: Aging of additively manufactured (AM) parts; PETG-CF specimens; Tensile test

Acknowledgement

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NUMERICAL ASSESSMENT OF STRUCTURAL INTEGRITY AND FATIGUE BEHAVIOR OF A MECHANISM FOR TRANSPORTING THE PLATFORM FOR PASSENGERS WITH REDUCED MOBILITY

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Abstract

This paper presents an assessment of the structural integrity and fatigue life of an innovatively designed platform transport mechanism for persons with disabilities integrated into aircraft boarding stairs. This platform transport mechanism on rails with variable stair inclination angles enables the safe transport of wheelchair passengers to door openings at various heights across different aircraft types. A detailed numerical investigation based on the finite element method (FEM) was performed to evaluate stress distribution, deformation fields, and potential failure zones within critical load-bearing components such as rails, shafts, and bearing housings, under cyclic operational loads. Different simulations were performed to predict fatigue life and identify critical points of stress concentration. The results indicate that the proposed design of the mechanism ensures sufficient stiffness and stability during operation while maintaining safety in accordance with relevant aviation and accessibility standards.

Failure and fatigue analyses highlight the most stressed areas in the adjustable rail assembly, which were further optimized through geometry refinement and material selection. The developed system increases passenger safety, operational efficiency, and accessibility while reducing physical assistance requirements. The presented research demonstrates how advanced simulation tools contribute to the design validation and life estimation of complex mechanical systems exposed to cyclic and variable loads.

Keywords: structural integrity; fatigue life; FEM simulation; mechanical design, cyclic loading

Acknowledgement:

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AN INVESTIGATION ON C. ELEGANS INSPIRED AUXETIC STRUCTURES

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Abstract

The re-entrant auxetic topology is one of the popular unit cells used to build cellular auxetic structures for energy-absorbing applications. However, there exists a considerable scope for enhancing its design by smoothening the sharp connecting edges of such structures. The present work explores a novel modification to the re-entrant auxetic design, drawing inspiration from the biological morphology of *Caenorhabditis elegans* (*C. elegans*) and investigates the mechanical response of such a modified auxetic structure with *C. elegans*-inspired curved-shaped geometries using commercially available finite element (FE) models. First, one convergence cum validation study was conducted to validate the FE Model, and then new responses were obtained for the *C. elegans*-inspired re-entrant auxetic structures. The results have been compared with those of a traditional re-entrant structure having similar relative densities and showed that the modified topologies demonstrate significantly improved energy absorption and specific energy absorption (SEA) capabilities. In addition, all the proposed new topologies exhibit better negative Poisson's ratio (NPR). This work confirms the potential of biologically inspired auxetic mechanical metamaterials, which can be designed to obtain tailored mechanical properties while improving the energy absorption capability of the system.

Keywords: C.Elegans; Bioinspired topology; auxetic structures; dynamic analysis; finite element modelling

CORROSION INDUCED FAILURE OF GAS CYLINDER – TWO CASE STUDIES

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Abstract

Small gas cylinders (SGC) are convenient and common types of vessels for various gas storage, from home to laboratories, various shops, and medical institutions. Improper use and regular maintenance of SGC can lead to catastrophic failures or gas storage ability loss. The analysis of corrosion-induced failures is an important object of study and always a valuable resource of common knowledge. This paper analyzes two SGC failures, one with a catastrophic burst and the second one, the leakage of gas through the wall. The failure analysis for both cases will be presented briefly and followed by the root cause failure analysis. The authors will present the suggested remedy for the prevention of failures. For both case studies, failure was triggered by corrosion, which will be discussed based on the presented results. Procedures of regular maintenance and inspection will be discussed, too.



First case study



Second case study

Figure 1. Examples of case studies

Keywords: gas cylinder, steel, corrosion, burs, failure

Acknowledgement

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THE EFFECT OF WELDING PROCESS ON STATIC AND FATIGUE BEHAVIOR OF HIGH-STRENGTH STEEL WELDED JOINTS

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Abstract

High-strength steels (HSSs) are developed to conjugate high load-bearing capacity with lightness and for this reason are widely used in weight-sensitive structural applications. Nowadays, for this application, welding is the most common process used to join two components. For this reason, it is important to evaluate the effect of different welding processes on static and fatigue behaviour of welded joints. In this paper, the influence of welding processes on static and fatigue behaviour was studied. Two types of butt-welded joints were made by means Gas Metal Arc Welding (GMAW) and Laser Beam Welding (LBW) process. After that, the microstructure and hardness were analysed to evaluate the effects of the welding processes on dimensions of the heat affect zone and the morphology of joints. Finally, static and fatigue tests under constant amplitude loading were carried out. The results show that joints made using the LBW process have a higher fatigue life than joints made with GMAW process.

Moreover, further developments along this line of research are currently in progress.

Keywords: High-strength steels; LBW; GMAW; welding; fatigue

CONDUCTIVE POLYMERS

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Abstract

Conductive polymers represent a class of materials with remarkable properties, blending the flexibility and processability of polymers with the electrical conductivity of metals. In recent years, there has been a surge of interest in exploring the diverse applications of conductive polymers across multiple industries. This paper provides a comprehensive review of the recent advances and emerging trends in the application of conductive polymers. It covers various fields including electronics, energy storage, sensing, biomedical devices, and more. The synthesis methods, properties, and performance of conductive polymers in each application are discussed, along with the challenges and future prospects.

Keywords: Conductive polymer; Doping level; Electroactive polymer

OPTIMIZATION OF THE DEBINDING AND SINTERING PROCESS OF FFF 3D-PRINTED AISI 316L SAMPLES

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Abstract

The effect of some process parameters of the debinding and sintering process for 3D-printed AISI 316L stainless-steel samples produced through Fused Filament Fabrication using BASF Ultrafuse 316L filament has been evaluated in this work. Disk-shaped samples (thickness 2 mm, diameter 30 mm) have been printed with Ultimaker 3D (layer height 0.15 mm, printing temperature 240°C, printing speed 30 mm/s). On the green body samples, chemical debinding was carried out by immersion in nitric acid (HNO₃) to remove part of the polymeric binder followed by a combined thermal debinding (T= 600°C, 1 h) and sintering cycle (T=1380°C, 3h) performed in a single furnace run in reductive (Ar-3%H₂) atmosphere. Thermogravimetric analysis (TGA) and Fourier Transform Infrared Spectroscopy (FT-IR) were used to monitor the binder removal and to evaluate the organic residues after each debinding step. For the sintering, the densification level of the specimens was also assessed to evaluate the effectiveness of the process and the influence of different treatment parameters. Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) analyses were carried-out on the surfaces and the cross-sections of the sintered samples while Vickers micro-hardness test was performed to evaluate the mechanical properties.

The FT-IR and the TGA analyses revealed that the binder is mainly composed of polyoxymethylene (POM) which shows a two-steps degradation process at T= 150 °C and T= 320 °C. Moreover, the analyses confirmed that the combination of chemical and thermal debinding is effective in the complete removal of the POM binder. The results for the sintered samples show that oxidations and inhomogeneities are common and widely present in the in-house sintered samples, highlighting the critical influence of both chemical and thermal treatments on the final microstructure and quality of the sintered parts.

Keywords: AISI 316L; FFF; 3D Printing; Debinding and sintering; FT-IR; TGA

INTEGRATED 3D DIC AND PRTS ANALYSIS OF LONG-TERM DEGRADED POWER PLANT STEEL

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Abstract

This paper presents an experimental investigation of the stress–strain behavior of Pipe Ring Tensile Specimen (PRTS) made of X20CrMoV12-1 power plant steel after 200,000 hours of service. The objective was to determine the hoop-direction mechanical response of the material using a 3D Digital Image Correlation (3D DIC) method, evaluate dimensional changes with a 3D scanning system, and record temperature field evolution using a thermal imaging camera during tensile loading. A total of 12 PRTS samples were prepared from two pipe segments: the fracture zone segment I and a straight-pipe segment II. The results show that the fracture forces of segment I specimens are lower compared to II due to material degradation near the crack region and reduced wall thickness. Cross-sectional analysis revealed pronounced ductile behavior, with an average thickness reduction of 40.1% and width reduction of 23.5%. Experimental stress–strain curves provided characteristic mechanical values, including an engineering ultimate strength of 367.47 MPa (463.4 MPa true value) and a 0.2% offset yield strength of 208 MPa. Comparison with the theoretical Ramberg–Osgood curve for X20CrMoV12-1 showed good agreement in the elastic region, with notable deviations in the plastic domain caused by long-term service exposure. The findings demonstrate that the PRTS methodology combined with 3D DIC offers a reliable approach for assessing material degradation and remaining load-bearing capacity of power plant tubing in the hoop direction without flattening and without introducing additional residual stresses.



Figure 1. Prepared PRTS

Keywords: Pipe Ring Tensile Specimen; X20CrMoV12-1; 3D DIC; Hoop stress–strain behavior; 3D scanning

Acknowledgement

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DIMENSIONAL ACCURACY ASSESSMENT OF 3D-PRINTED CT SPECIMENS PRODUCED BY SELECTIVE LASER SINTERING

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Abstract

Additive manufacturing is increasingly used for producing standardized fracture-mechanics specimens, allowing the fabrication of Compact Tension (CT) samples with complex geometries that would be difficult to machine conventionally. However, the dimensional accuracy of selective laser sintering remains a crucial factor for ensuring reliable mechanical and fracture-toughness measurements. In this study, the geometric accuracy of 3D-printed cobalt–chromium CT specimens was evaluated by comparing three design variants to their corresponding CAD reference models. Optical scanning and qualitative surface-deviation mapping revealed that differences in accuracy were strongly influenced by specimen geometry, particularly in regions involving sharp transitions and stress-concentrating features. While some designs showed noticeable deviations attributable to manufacturing complexity, others remained within acceptable tolerance limits for fracture testing, requiring minimal post-processing. These findings underscore the importance of carefully optimizing build orientation, scanning strategies, and post-processing protocols when using additive manufacturing to produce CT specimens intended for high-precision mechanical characterization.

Keywords: CT specimens; Additive manufacturing; Selective laser sintering; Dimensional accuracy; Optical scanning; Fracture mechanics testing

Acknowledgement

The results presented here are the result of research supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under Contract 451-03-137/2025-03/200105 dated 04.02.2025.

RELIABILITY-CENTERED MANUFACTURING

- A. S. Popović, M. Miličić Lazić, D. Mitić, L. Rakočević, D. Jugović, P. Živković, B. N. Grgur - *Surface Engineering of Titanium Implants via Anodization: Enhancing Electrochemical Stability and Cellular Response for Long-Term Biocompatibility*
- R. Sousa, S. Fernandes, A. Andrade, P. Alves, J. Silva, T. Domingues,, P. Moreira, V. Infante - *Application of predictive maintenance to freight transport wagons*
- M. S. I. Elsayed, T. El-Fakharany, S. Khaled, I. Martić - *Torque and Drag Optimization By Using Mechanical Specific Energy*
- C. Qi - *The theoretical model for combined sample size and strain rate effect on tensile strength of quasi-brittle materials*
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- L. Pan, P. Ding, C. Gong, Y. Chen, X. Zheng - *Accelerated degradation of 316LN under stress-assisted corrosion in oxygen-saturated liquid sodium*
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- A. Milivojević, M. Stamenić, V. Adžić - *Risk assessment for hydrogen installations*

SURFACE ENGINEERING OF TITANIUM IMPLANTS VIA ANODIZATION: ENHANCING ELECTROCHEMICAL STABILITY AND CELLULAR RESPONSE FOR LONG-TERM BIOCOMPATIBILITY

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Abstract

The long-term success of titanium-based biomedical implants is strongly influenced by their surface properties, corrosion resistance, and biological compatibility. This study aims to systematically evaluate the effects of anodic oxidation on the electrochemical stability and biocompatibility of commercially pure titanium (cpTi, grade IV), with a focus on its application in dental and orthopedic implants. Anodization was performed in 1 M H₂SO₄ at a constant voltage of 15 V for 15 and 45 minutes to produce oxide layers of varying thickness and surface characteristics.

Surface morphology and chemical composition were characterized using SEM coupled with EDS, while X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) were utilized to elucidate and observe the phase transitions of the synthesized titanium oxides. The oxide layer thickness was estimated using a frequency-dependent capacitance method, revealing values of approximately 40 ± 15 nm and 90 ± 30 nm for 15- and 45-minute treatments, respectively. Corrosion performance was assessed in 9 g L⁻¹ NaCl (pH 7.4), demonstrating superior corrosion stability of anodized samples compared to untreated cpTi. Cyclic polarization tests confirmed the absence of pitting corrosion, indicating that oxygen evolution was the predominant electrochemical process.

Biocompatibility was evaluated by examining mitochondrial activity and gene expression in human gingival fibroblasts. The anodized surfaces, particularly those treated for 45 minutes (Ti-45), enhanced cellular adhesion and spreading. Both experimental groups, Ti-15 and Ti-45, showed a significant upregulation of N-cadherin and Vimentin. Additionally, the anodized surfaces exhibited improved hydrophilicity and elevated surface energy values, rising from 58.8 mJ m⁻² for untreated Ti to 65.1 mJ m⁻² for Ti-45.

The results highlight that anodic oxidation not only improves corrosion resistance but also enhances surface-driven cellular responses, supporting its potential use in optimizing implant integration and longevity in physiological environments.

Keywords: Wettability; Corrosion Measurements; Titanium oxide; Biocompatibility

Acknowledgement

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APPLICATION OF PREDICTIVE MAINTENANCE TO FREIGHT TRANSPORT WAGONS

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Abstract

The equipment maintenance has become increasingly vital in response to the growing demands of modern industry. In this context, predictive maintenance plays a key role in enhancing equipment availability. In this study the methodology RCM (Reliability-Centred Maintenance) was applied to a railway wagon (Figure 1) fleet to identify and assess risks associated with potential failure modes (using FMECA methodology) and developing appropriate strategies for their management and mitigation. This RCM analysis was developed as part of the SMARTWAGONS project, carried out at the MEDWAY Maintenance & Repair facilities in Entroncamento. The results showed that the risks associated with four failure modes were successfully mitigated. Maintenance tasks were also proposed based on condition monitoring, with a strong emphasis on predictive maintenance, supported by the installation of sensors on the wagon under study.



Figure 1. Railway wagon

Keywords: Predictive Maintenance; Availability; RCM; FMECA

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TORQUE AND DRAG OPTIMIZATION BY USING MECHANICAL SPECIFIC ENERGY

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Abstract

Torque and drag optimization is a process that employs drilling parameter and surface equipment, computer software, down hole equipment and experienced expert personnel – all dedicated to reduce torque and drag trouble time and increase drilling efficiency.

Torque and drag optimization by surveillance mechanical specific energy are mandatory and will reduce the drill string failure during the drilling operation and increase drilling efficiency. This will impact on total non-productive time which reduced with roughly 50% compared to normal practice and leads also to complete the well safely to reach the target, and all above lead to cost optimizing with roughly 30% compared to normal practice.

The study was done on six wells directional and vertical by surveillance MSE and found that the major parameter effected on torque and drag is vibration pattern and friction factor and found that to make drilling efficiency keep surface parameter reach to it without propagation in vibration or friction to get more torque on bit more rate of penetration so working on improvement capacity and maximize parameter reach to bit is the key to have more efficiency drilling and also more valuable as following:

- Less Maintains
- Higher Efficiency
- High operation durability
- less capital cost

The above results reaching by surveillance of MSE working on monitoring the energy required to destroy the formation.

Six wells using for study 3 wells using surveillance MSE for monitoring torque and drag and 3 wells not using MSE. The optimization of torque and drag by surveillance MSE impacted on NPT less percentage 50 % from the well not monitor by MSE and also reduce the stuck probability by 80% from the original condition.

The six wells studying by surveillance MSE in 5 wells and 5 well not using MSE for monitoring. The optimizer selected the operating point with lowest MSE among torque-safe candidates — that point gives best drilling energy efficiency in the sample. In real wells you should use down hole torque predictions and include other constraints (vibration, BHA limits, and mud properties).

Deploy as a real-time advisor: compute rolling MSE, predict down hole torque with your torque & drag model, and recommend moves toward the lowest-MSE settings while ensuring predicted torque stays below.

Keywords: Mechanical Specific Energy; Drag; Torque; Friction factor; Revolution per minute

Acknowledgement

I would like to devote a special thanks to Dr. Aya Gamal my beautiful wife for great help and support during my work.

THE THEORETICAL MODEL FOR COMBINED SAMPLE SIZE AND STRAIN RATE EFFECT ON TENSILE STRENGTH OF QUASI-BRITTLE MATERIALS

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Abstract

Under external loads, tensile strength of quasi-brittle materials, such as rock and concrete, exhibits size and strain rate effects. Experiments have shown that the size effect and strain rate effect interact with each other. Based on the fact that the strength of solid material is the superposition of the thermal activation strength component under quasi-static loading and the macroscopic viscous component under dynamic loading, by using the static size effect laws of tensile strength, the thermal activation theory of material deformation and failure, Weibull's model of random local strength of materials and crack dynamics, theoretical model for the combined sample size and strain rate effect on tensile strength of quasi-brittle materials is established, which cover wide strain rate ranging from low strain to high strain rate. The theoretical model is validated by comparing its prediction with experimental data. Finally, the weakening effect of strain rate on material strength at high strain rate is incorporated into the proposed model. The developed here theoretical model provides the better understanding of the combined sample size and strain rate effect on tensile strength of quasi-brittle materials.

Keywords: Quasi-brittle materials; strain rate; Weibull's model

NOVEL LOAD SEPARATION METHOD FOR ACCURATE η_{pl} AND γ_{pl} ESTIMATION AND ERNST EQUATION LIMITATIONS

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Abstract

The η_{pl} and γ_{pl} are two geometrical factors required for J-integral-based fracture toughness testing and fracture toughness evaluation in terms of J_Q , J_{IC} and J - R curves. These geometrical factors can be estimated by domain integral (DI) and limit load methods using FEM or through the load separation (LS) method experimentally or through FEM. The LS method is reported to be the most accurate as it requires only load-displacement data to calculate these factors. The LS method developed by Sharobeam and Landes uses a fitted relation between the separation parameter (S) and b/W to calculate these factors. They recommended using a power law relation between S and b/W to calculate the η_{pl} factor. The problem with the power law fit is that, irrespective of the fracture specimen geometry, it always gives constant values of η_{pl} and γ_{pl} factors. Here, we have used clamped SENT and CCT specimens to show that polynomial fits give more accurate values of these factors compared with the DI method and LS method using power law fit. For the clamped SENT specimen, the η_{pl} factor obtained from the novel LS method increases monotonically with b/W compared with the value obtained from the DI method, which increases and then decreases with b/W (Fig. 1a). The γ_{pl} factor obtained from the novel LS method is always positive, whereas the DI method gives negative values of the γ_{pl} factor after a certain b/W (Fig. 1b).

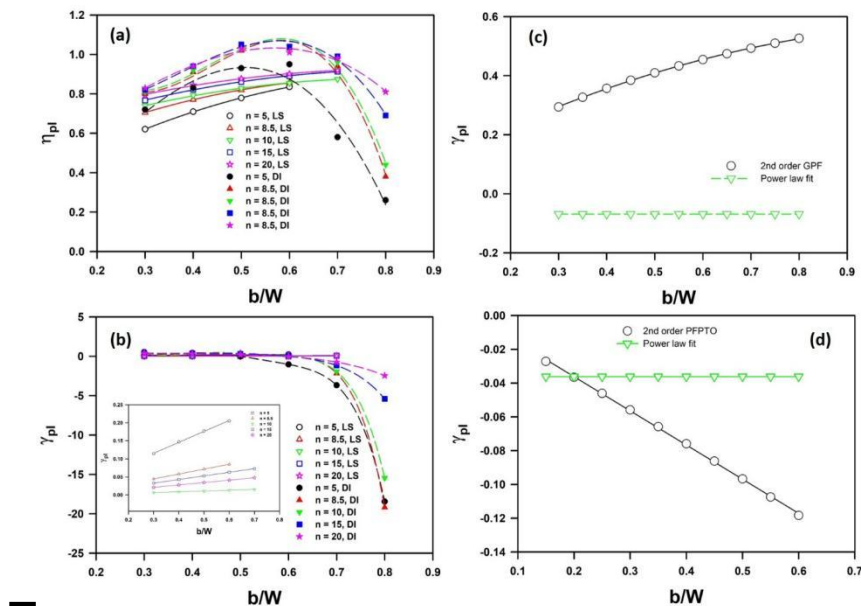


Figure 1. Comparison of (a) η_{pl} and (b) γ_{pl} factors of clamped SENT specimen for different values of n , comparison of γ_{pl} factors of (c) clamped SENT and (d) specimen evaluated using novel LS method and LS method using power law fit.

The novel LS method gives a positive γ_{pl} factor, whereas the LS method using power law fit gives constant and negative values of the γ_{pl} factor (Fig. 1b). Since the value of the γ_{pl} factor cannot be negative, this demonstrates the accuracy of the novel LS method over the DI method and LS method using power law fit. Even with the novel LS method, the γ_{pl} factor is negative for the CCT specimen (Fig. 1d). Since the value of the γ_{pl} factor cannot be negative, the negative value of the γ_{pl} factor suggests that there is some problem in Ernst's equation for calculation of J_{pl} for growing cracks, and there is an urgent need to develop a correct equation for calculation of J_{pl} for growing cracks.

Keywords: η_{pl} and γ_{pl} factors; J-integral; load separation method; Ernst equation; growing crack

RELIABILITY ANALYSIS OF SHELL STRUCTURES UNDER SMALL FAILURE PROBABILITIES USING ADAPTIVE MULTI-FIDELITY SAMPLING

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Abstract

Reliability analysis of complex engineering structures faces significant computational challenges, particularly when estimating small failure probabilities that are critical for aerospace safety requirements. The high computational cost of evaluating limit state functions through numerical methods such as finite element or boundary element analysis often makes direct Monte Carlo simulation prohibitive. This study employs the Global-Error Active Learning Function (GEALF) method, which strategically selects training points to maintain accuracy while substantially reducing computational demands. The approach is further enhanced through multi-fidelity modelling, using low-fidelity models for global exploration and reserving computationally expensive high-fidelity evaluations for critical regions near the limit state. The methodology is demonstrated through two examples. First, a two-dimensional analytical multimodal function validates the approach against Monte Carlo simulation, achieving errors below 1.32% with only 36 high-fidelity and 75 low-fidelity evaluations compared to the benchmark Monte Carlo samples. Second, a shallow shell structure under cabin pressure is analysed and the stress intensity factor was evaluated using the Dual Boundary Element method. The multi-fidelity approach requires approximately 35 high-fidelity and 80 low-fidelity evaluations, compared to the 267 training points needed for traditional Kriging-based Monte Carlo simulation. This shows a computational cost reduction of around 60% in terms of numbers of high-fidelity calls. While relative errors increase for very small failure probabilities (reaching 5.43% at $\sim 10^{-6}$), the accuracy remains within acceptable level.

Keywords: Reliability analysis; Multi-fidelity model; Shallow shell structure; Boundary Element method

Acknowledgement

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ACCELERATED DEGRADATION OF 316LN UNDER STRESS-ASSISTED CORROSION IN OXYGEN-SATURATED LIQUID SODIUM

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Abstract

Sodium-cooled fast reactors (SFRs), as representative Generation IV systems, operate at elevated temperatures (550–700°C) where structural materials are subjected to severe thermo-mechanical loads and corrosive liquid sodium environments. Type 316LN stainless steel, commonly employed in heat transfer components, is particularly vulnerable when dissolved oxygen is present. While numerous studies have addressed sodium corrosion or long-term mechanical properties individually, the combined effects of stress and sodium corrosion remain insufficiently understood, especially under oxygen-saturated conditions. In this study, creep fracture tests and static corrosion experiments were performed on 316LN stainless steel in oxygen-saturated liquid sodium at 700°C, with comparative tests in air. Post-test characterization of surface morphology, elemental redistribution, and microstructural evolution was carried out to clarify the degradation mechanisms. Results show that applied stress significantly accelerates sodium corrosion through stress-enhanced diffusion, grain boundary weakening, and surface film disruption, leading to deeper corrosion penetration and premature fracture. The creep life of 316LN in oxygen-saturated sodium was markedly reduced, in some cases falling below the RCC-MRx minimum design curve, indicating that current design assumptions based on low-oxygen data are inadequate. A diffusion-based predictive model was further developed, showing a strong correlation ($R^2 > 0.97$) between corrosion depth, applied stress, and exposure time, thus providing a reliable tool for service-life prediction. Overall, this work highlights the critical role of stress-assisted corrosion under high-oxygen sodium conditions and underscores the necessity of incorporating such interactions into the safety design and lifetime assessment of SFR structural materials.

Keywords: Sodium corrosion; High-temperature; 316LN stainless steel; Creep, Stress-Corrosion interaction

Acknowledgement

This work was financially supported by the National Natural Science Foundation of China (52275159, 51975424).

²INFLUENCE OF DELTA FERRITE AND PRECIPITATES ON IMPACT ENERGY OF NICKEL FREE AUSTENITIC STAINLESS STEELS

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Abstract

This study examines the influence of delta ferrite and precipitates (secondary phases) on the impact energy of nickel-free austenitic stainless steels. Alloys with delta ferrite and precipitates content ranging from 8 to 19 vol% were produced by controlled adjustment of Cr, Mn, Mo and N and solution annealing treated at 920 °C, 1020 °C and 1100 °C. Besides varying the solution annealing temperature, the duration of solution annealing was also adjusted. The microstructures were characterized by optical microscopy and SEM. Precipitates formed at grain boundaries have the most significant effect on reducing impact energy. As the precipitate density per mm² increases, the impact energy decreases accordingly. The character of the precipitate plays a crucial role, especially in terms of its coherence or incoherence with the matrix. Charpy V-notch tests at room temperature showed that steels containing up to approximately 10 vol% delta ferrite and precipitates exhibited good absorbed energy, i.e., toughness. However, higher levels of delta ferrite and precipitates (~14 vol%) led to brittleness, resulting in a ~40% reduction in toughness due to brittle fracture along delta ferrite boundaries. Samples with ~19 vol% delta ferrite and precipitates demonstrated a toughness drop of around 65%. These results highlight the importance of balancing delta ferrite content and precipitate morphology to optimize mechanical performance in nickel-free austenitic stainless steels.

Keywords: Delta ferrite; nickel-free austenitic stainless steel; impact energy; precipitates; toughness

PROGRESS OF SMALL PUNCH TEST AND STANDARDIZATION IN CHINA

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Abstract

The small punch test (SPT) has advantages in obtaining mechanical properties of irradiated reactor material, due to the limited spaced of irradiation channel, the reduction of material consumption and lowering experimental costs. SPT is considered non-destructive, has a minimal impact on structural integrity, and requires much less material than conventional testing methods. This paper summarizes the progress of SPT in creep, tensile and fracture toughness properties and shows the phased achievements of d SPT technology research and development at home. Moreover, the process of standardization of SPT in China is also introduced, which improved the scientificity and reliability of material performance evaluation. Empirical correlation approach and formulae are recommended in the strength and fracture toughness in the standards. Combined structure with a penetrated slot and a U-groove was proposed on small punch sample to obtain fracture toughness. It can be expected that its application to assess the mechanical behavior for in-service equipment will increase.

Keywords: Small punch test; Standardization; Tensile property; Fracture toughness; Creep

QUANTITATIVE SAFETY ASSESSMENT OF LITHIUM-ION BATTERIES: FUZZY ANALYTIC HIERARCHY PROCESS INTEGRATING AGING, INTRINSIC SAFETY, AND ABUSE RISKS

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Abstract

Lithium-ion batteries (LIBs) are indispensable in electric vehicles, portable electronics, and energy storage systems owing to their high energy density and long cycle life. However, their widespread use has led to rising concerns regarding safety incidents such as fire and explosion, particularly under aging and abuse conditions. Conventional assessment methods typically focus on single abuse scenarios, such as thermal, electrical, or mechanical stress, and fail to capture the interplay between intrinsic safety parameters and external abuse risks. To overcome this limitation, we present a novel dual-model quantitative framework based on the fuzzy analytic hierarchy process (FAHP), enabling systematic integration of intrinsic safety characteristics with abuse conditions for both fresh and aged batteries.

Two complementary models were developed, case studies were performed on lithium cobalt oxide (LCO) pouch cells across different states of health (SOH), including fresh, moderately aged, and swollen batteries. Results show that gas generation is the dominant factor increasing safety risks in swollen cells, while aging tends to mitigate risks under thermal and electrical abuse by reducing available energy, though mechanical abuse risks remain largely unchanged. SEM provides a simple yet effective engineering assessment tool, while GSM delivers a detailed, accurate evaluation suitable for high-stakes safety management and research.

This study not only demonstrates that battery safety is a function of both intrinsic and abuse-related factors but also establishes a quantitative grading mechanism for LIB safety. By validating the models through experimental data and FAHP-based weighting, the approach offers a unified strategy for safety classification, lifecycle risk prediction, and recycling decision-making. These findings contribute to safer large-scale deployment of LIBs in transportation and energy sectors, while providing valuable guidance for industrial design, regulatory policy, and sustainable recycling strategies.

Keywords: Lithium-ion batteries; Safety assessment; Intrinsic safety; Abuse risks; Battery management

DESIGNING GRADIENT MICROSTRUCTURES TO SUPPRESS HYDROGEN DIFFUSION

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Abstract

Gradient microstructures produced by severe surface plastic deformation (SPD) offer a unique pathway to combine high strength, toughness, and resistance to hydrogen embrittlement (HE). Yet, the mechanistic link between such gradients and hydrogen transport remains unclear.

We developed a coupled simulation framework integrating severe shot peening with a hydrogen diffusion model explicitly accounting for dislocation structures and residual stress. The results show that gradient layers significantly suppress hydrogen diffusivity, but the benefit is not unlimited: thin layers have a reduced effect, and increasing shot-peening coverage beyond 100% yields only marginal improvement. Residual compressive stress and dislocation trapping retard hydrogen transport, while excessive grain refinement may create fast diffusion paths along grain boundaries. In contrast, twin boundaries act as effective barriers, suggesting that controlled twin-gradient architectures could provide superior hydrogen resistance.

A predictive model derived from these simulations links microstructural parameters to effective hydrogen diffusion coefficients, enabling rational design of SPD-processed steels and high-strength alloys. The findings demonstrate that hydrogen permeation depends not only on defect density but on the hierarchical arrangement and type of interfaces.

This work establishes a quantitative strategy for tailoring gradient microstructures to balance strength, toughness, and hydrogen resistance, providing guidance for next-generation materials in hydrogen energy, offshore, and aerospace applications.

Keywords: Hydrogen embrittlement; hydrogen traps; hydrogen diffusion; surface mechanical treatment

Acknowledgement

This work was supported by the National Natural Science Foundation of China under Grant No. 52405157, and the Postdoctoral Fellowship Program of CPSF under Grant No. GZC20231115.

EXPERIMENTAL AND NUMERICAL INVESTIGATION OF REHEAT CRACKING MECHANISMS IN 2.25Cr1Mo0.25V WELDMENTS

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Abstract

This study addresses the risk of reheat cracking in 2.25Cr1Mo0.25V steel welded joints. By integrating microstructural characterization, simulation of residual stress evolution, and C-ring reheat cracking tests, the formation mechanism during post-weld heat treatment (PWHT) is systematically revealed. The results show that the key role of heat treatment is to eliminate the severe microstructural segregation present in the as-welded state, which causes non-uniform properties, by promoting the dissolution of grain boundary carbides. Concurrently, PWHT significantly relieves macroscopic residual stresses, primarily axial and hoop stresses. This relief process is mainly controlled by the material's high-temperature yield strength during the heating stage; however, stress concentrations persist at locations such as the weld surface and the top of the back-gouged root. Ultimately, it was found that crack initiation originates from micro-scale stress concentrations induced by carbide precipitation, which is then exacerbated by non-uniform macroscopic residual stresses and abrupt changes in mechanical properties. This interplay between microstructural evolution and macro-stress distribution governs the reheat crack initiation mechanism of the joint. The correlation established in this study among microstructure, residual stress, and reheat cracking susceptibility provides crucial theoretical guidance for optimizing heat treatment processes and preventing structural failure.

Keywords: 2.25Cr1Mo0.25V steel; Post-weld heat treatment; Residual stress; Reheat cracking

Acknowledgement

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DEVELOPMENT OF A PREDICTIVE MODEL FOR PEELING FRACTURE BEHAVIOR OF BRAZED JOINTS BASED ON IN-SITU TESTING

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Abstract

The peeling test applied to the brazed joint structural mechanical performance testing can effectively solve the issue of evaluating the interface bonding strength of non-standard geometric brazed joints. Accurate acquisition of mechanical parameters and establishment of mathematical models are the foundation for forming a standardized peel testing framework for brazed joints. To achieve this, an in-situ peeling test was conducted to obtain peeling parameters, while strain and displacement data in the deformation zone (such as crack tip opening displacement and crack initiation strain) were directly obtained using digital image methods. Based on this, a mathematical model for peeling crack propagation was established to describe the macroscopic peeling crack propagation behavior, using images from the continuous dynamic peeling process. Furthermore, the peeling fracture energy was calculated using the compliance-based beam method. Finally, by integrating peeling parameters and material properties of brazed joints under various conditions, a hybrid model based on machine learning methods was developed, ultimately resulting in the establishment of an accurate predictive model for the peeling fracture behavior of brazed joints.

Keywords: Peeling fracture Brazed joint; Crack propagation; Peeling fracture energy; Machine learning

Acknowledgement

The work was supported by National Natural Science Foundation of China (Nos. 52130511, 52321002) and Shanghai Gaofeng Project for University Academic Program Development.

A QUANTILE-BASED NESTED ADAPTIVE KRIGING APPROACH FOR RELIABILITY-BASED DESIGN OPTIMIZATION OF HIERARCHICAL SYSTEMS

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Abstract

In recent years, reliability-based design optimization (RBDO) has garnered extensive attention from scholars and engineers. However, when targeted structures exhibit uncertainties across multiple scales or involve multiple computer simulations, resulting in complex hierarchical uncertainties propagation, the computational cost of RBDO increases substantially. Surrogate models are typically employed to enhance the efficiency of the overall RBDO process. For complex systems exhibiting hierarchical characteristics, this paper proposes a quantile-based adaptive surrogate-based RBDO method. Initially, the system is decomposed into multiple cascaded subsystems according to their scale or structural characteristics, and surrogate models are constructed for each. Subsequently, a hierarchical learning function is utilized to adaptively refine the surrogate models. Moreover, a novel constraint importance evaluation index is established to further improve optimization efficiency. Finally, the proposed algorithm is validated through a welded beam design optimization case study, and the results demonstrate its superiority over conventional black-box RBDO approaches.

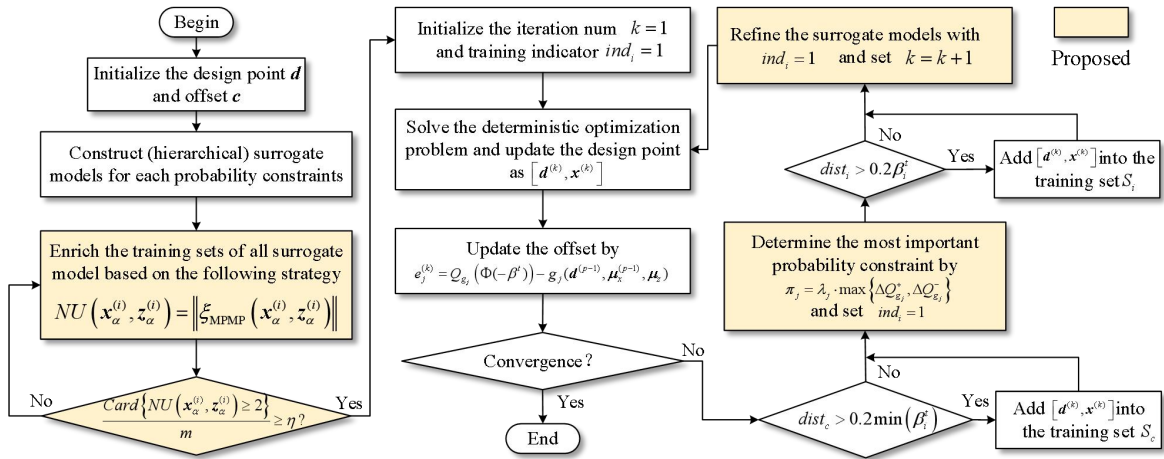


Figure 1. Quantile-based nested adaptive Kriging-based RBDO method

Keywords: Reliability-based design optimization, hierarchical framework, adaptive surrogate models, constraint importance evaluation

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RISK ASSESSMENT FOR HYDROGEN INSTALATIONS

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Abstract

Hydrogen is increasingly being adopted as a clean energy carrier across various industries, including transportation, power generation, and chemical processing. However, due to its unique physical and chemical properties—such as high flammability, low ignition energy, and wide flammability range—hydrogen poses specific safety challenges that must be carefully assessed and managed. This study presents a comprehensive risk assessment for hydrogen installations, focusing on identifying potential hazards, evaluating the likelihood and consequences of hazardous events, and assessing the effectiveness of existing safety barriers.

Keywords: Hydrogen installations; power generation; high flammability; risk assessment; safety barriers

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THE UNIVERSAL FAILURE CURVE APPLIED TO REPURPOSING NATURAL GAS PIPELINES TO HYDROGEN SERVICE: ASSESSMENT OF SAFETY MARGINS AND COMPARISON WITH ASME B31.12.

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Abstract

The Universal Failure Curve (UFC) has been recently proposed by the author and co-workers as damage tolerance design approach which enables the used of normalised global stress (e.g. membrane, bending) and a configurational normalised fracture toughness to define conditions to failure. The methodology is derived from fracture mechanics principles, and its formulation has been derived using using a dataset of 588,000 cases generated with API 579 procedures and validated with experimental data obtained from the literature, including burst pressure tests, fracture tests of panels and welded components. In this paper the UFC is used to interrogate ASME B31.12 design procedure and to evaluate the safety margins derived from its application. Results show that safety margins for the higher grades (e.g. X80) are small for the minimum required toughness values in the performance-based approach in ASME B31 are used for operating pressures leading to hoop stresses of 72% SMYS. The approach allows target safety margins to be defined by using more refine values of operating pressure and estimates for the normalized toughness (mainly K_{mat} , a)

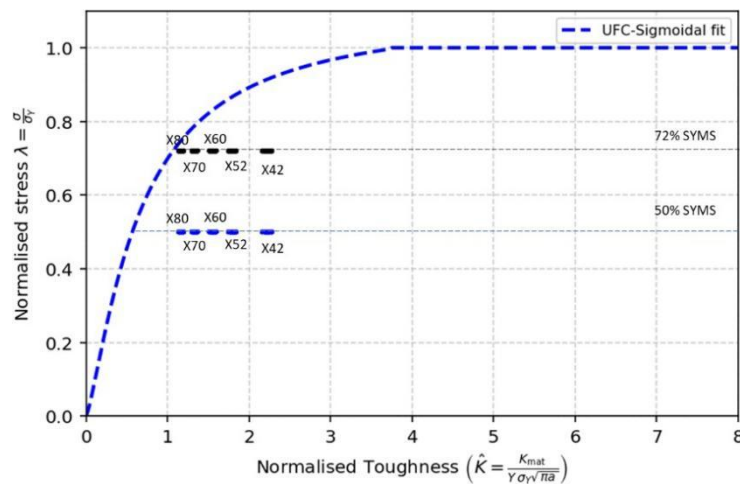


Figure 1. ASME B31.12 performance-based design approach interrogated by the UFC

Keywords: Universal Failure Curve, damage tolerance design, hydrogen , ASME B31.12

NOVEL INSIGHTS INTO CREEP-FATIGUE INTERACTION UNDER UNCOMMON WAVEFORMS

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Abstract

Creep-fatigue interaction critically limits the service life of components in high-temperature power plants. This study investigates Type 316L austenitic stainless steel under two asymmetric load waveforms: slow tension-fast compression (S-F) and fast tension-slow compression (F-S), providing novel insights into creep-fatigue behaviour under unconventional loading conditions. To address this knowledge gap, a comprehensive macro- and micro-mechanical approach was employed, involving high-temperature fatigue and creep-fatigue testing at 550 °C, post-mortem scanning electron microscopy, X-ray computed tomography, in-situ neutron diffraction, and crystal plasticity modelling. High temperature tests revealed that the S-F waveform significantly shortened fatigue life compared with F-S waveform and induced greater creep strain accumulation during tensile dwell. Post-mortem scanning electron microscopy and X-ray computed tomography revealed that creep-fatigue S-F loading promoted intergranular fracture and increased the fraction of medium-sized defects. In-situ neutron diffraction demonstrated that the S-F waveform caused higher grain-level deformation incompatibility. Crystal plasticity modelling attributed the higher tensile stress amplitudes in S-F waveform to increased dislocation densities, linking microstructural evolution to macroscopic responses. These findings provide mechanistic insights into creep-fatigue interaction under asymmetric loading and offer a framework for designing cost-effective accelerated tests.

Keywords: Creep-fatigue interaction; Asymmetric waveforms; Fracture mechanics; Grain-level deformation; Crystal plasticity modelling

Acknowledgement

This work was supported by the UK Engineering and Physical Sciences Research Council (EPSRC) through the Early Career Fellowship Scheme (EP/R043973/1) awarded to Bo Chen. The authors gratefully acknowledge the ISIS Neutron and Muon Source (UK) for providing ENGIN-X beamtime (RB2010070) and the UK High Temperature Facility (HTF) Alliance for granting access to the creep-fatigue testing rig. We also acknowledge the use of the Advanced Microscopy Facility at the University of Leicester, including access to the Hercules instrument funded by the EPSRC Strategic Equipment Scheme (EP/X014614/1), Correlative Analysis of Crystals in 3D.

FAILURE ANALYSIS ON 2ND STAGE ROTOR IMPELLER OF AN AIR COMPRESSOR

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Abstract

Significant damage and multiple cracks were detected in the 2nd stage impeller of an air compressor located at the production facility in Smederevo, as shown in Fig. 1, following its failure. This impeller had been in continuous service for over 15 years under high rotational speeds and variable loading conditions and was replaced in 2020 after cracks were discovered in the 2nd stage impeller.

The failure analysis included material characterization, static stress analysis under different operational scenarios, and evaluation of fatigue crack growth due to cyclic rotational loading. Fracture mechanics principles were applied to assess structural integrity and remaining service life. A Failure Assessment Diagram was constructed based on the assumed initial flaw size, while the crack growth rate and predicted life of the impeller were determined using Paris law, providing essential input for inspection planning and preventive maintenance strategies.



Figure 1. Cracks in 2nd stage impeller of an air compressor

Keywords: Failure analysis; Air Compressor; impeller; structural integrity and life

Acknowledgement

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THE UNIVERSAL FAILURE CURVE AS AN ALTERNATIVE APPROACH TO FAD AND CDF FRACTURE ASSESSMENT METHODS

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Abstract

An interaction diagram for design and structural integrity assessment is developed. The method, termed the Universal Failure Curve (UFC), employs a normalised global stress and a configurationally normalised fracture toughness to define conditions to failure. The UFC uses the same terminology of the Failure Assessment Diagram (FAD) framework but eliminates the need for multiple intermediate calculations by expressing the limiting condition directly in terms of design-relevant parameters and without the need to explicitly calculate the plastic collapse parameter as this is an outcome of the analysis. Residual stress effects are incorporated through a proportionality factor (δ), leading to δ -UFCs that allow direct adjustment of the baseline curve for different residual stress levels. The methodology is derived from fracture mechanics principles and plastic collapse conditions, and its formulation is validated using a dataset of 588,000 cases generated with API 579 procedures, as well as experimental results from the literature. The UFC reproduces the trends of FAD and Crack Driving Force approaches while maintaining equivalent levels of conservatism, thereby providing a basis for damage tolerance design and assessment of structures containing defects.

Keywords: Artificial Intelligence; X-ray Image Analysis; NDT Automation; Defect Detection; Machine Learning

AN EXPERIMENTAL STUDY OF FATIGUE PROPERTY ENHANCEMENT IN 310S STAINLESS STEEL DUE TO SURFACE MECHANICAL ROLLING TREATMENT

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Abstract

Surface mechanical rolling treatment (SMRT) is a repeated rolling process that refines grains and induces a gradient nanostructured or ultrafine grained layer on the surface of the processed component, which results in an enhancement in the fatigue properties. Several major factors contribute to the improved fatigue properties of metallic materials after SMRT. The current study employed a fully austenite 301S stainless steel which does not undergo stress-induced martensitic transformation. After the SMRT process, the round testing specimens were subjected to fully reversed strain-controlled fatigue loading. The fatigue results reveal that without martensitic transformation, the SMRT process enhances both the fatigue strength and fatigue ductility significantly, implying that martensite and martensitic transformation are not a necessary element in the enhancement of the fatigue properties by SMRT for an austenite stainless steel. To study the influence of the residual stresses, a strain-controlled incremental decreasing loading spectrum was applied on the SMRT processed specimens to relax the residual stresses. By comparing the results obtained by the SMRT process and those with residual stress relaxed after SMRT, it is demonstrated the residual stresses play an insignificant role in the observed enhancement in fatigue properties by SMRT.

Keywords: Surface process; Fatigue strength; Fatigue ductility

Acknowledgement

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EFFECT OF HYDRIDES ON LOW-CYCLE FATIGUE CRACK INITIATION IN Ti-2Al-2.5Zr TITANIUM ALLOY: EXPERIMENTAL AND CRYSTAL PLASTICITY METHODS

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Abstract

In titanium alloy heat exchange tubes, high-pressure hydrogen, an antioxidant, is introduced into the internal cooling water. Due to the low solubility of hydrogen in titanium, hydrides precipitate as a second phase. This study aims to clarify the effect of hydrides on the low-cycle fatigue crack initiation behavior of Ti-2Al-2.5Zr alloy and provide guidance for the structural reliability design of titanium alloy heat exchanger tubes. Low-cycle fatigue tests were conducted on hydrogen-charged Ti-2Al-2.5Zr alloy. Crack nucleation and evolution process were observed via quasi-in-situ interruption tests. The microcrack initiation characteristics were analyzed based on the characterization results from SEM, EBSD, AFM, and FIB techniques. Additionally, combined with crystal plasticity finite element method, the fatigue crack initiation mechanism of the hydrogen-charged Ti-2Al-2.5Zr alloy was clarified. The study found that the deformation incompatibility between the hydride and titanium matrix promotes strain localization near the phase interface, resulting in severe damage accumulation at the phase boundary on the free surface of the specimen. This facilitates crack initiation at the phase boundary and accelerates the fatigue failure process.

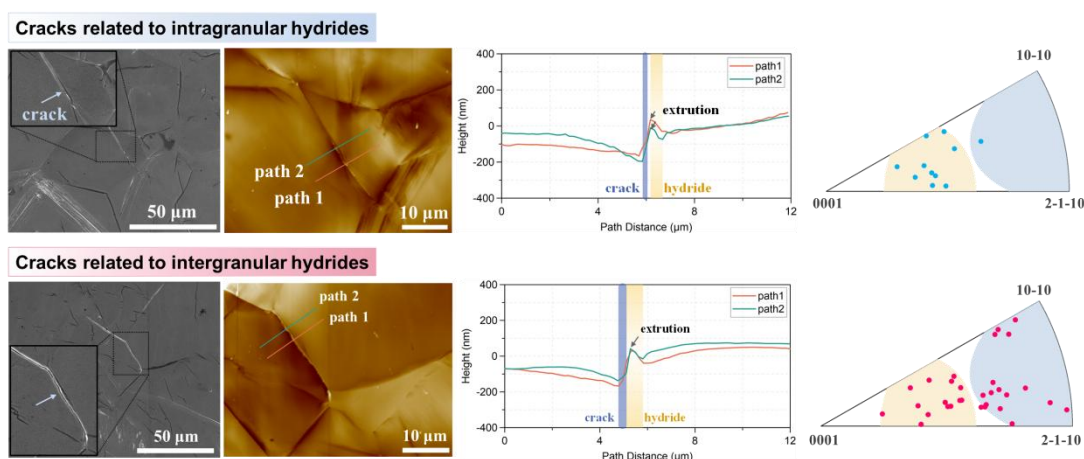


Figure 1. Hydride-related crack initiation characteristics

Keywords: Hydrides; Titanium alloy; Fatigue; Crack initiation

Acknowledgement

The authors gratefully acknowledge financial support from the National Natural Science Foundation of China (No. 52375155).

EFFECT OF LOW-TEMPERATURE GASEOUS CARBURIZING ON THE FRETTING FATIGUE BEHAVIOR OF AISI 316L AUSTENITIC STAINLESS STEEL

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Abstract

Fretting fatigue is a critical failure mode that severely limits the service life of metal components in engineering applications. To enhance the fretting fatigue properties of AISI 316L austenitic stainless steel, low-temperature gaseous carburization (LTGC) was employed as a surface treatment. In this study, fretting fatigue tests under a stress ratio of 0.1 were conducted to determine the S–N curves and fatigue limits of both untreated and carburized specimens. These tests allowed assessment of the influence of LTGC on the fretting fatigue performance of AISI 316L. The results demonstrate that LTGC forms a uniform hardened layer (~30 μm) on the surface of AISI 316L, introduces high compressive residual stress (~2 GPa), and increases the surface hardness to ~1000 HV. Consequently, LTGC significantly enhances the fretting fatigue properties of AISI 316L. Additionally, the fretting fatigue fracture surfaces and wear morphology of the specimens were investigated to elucidate the mechanism by which LTGC enhances fretting fatigue properties.

Keywords: Fretting fatigue; Low-temperature gaseous carburization; AISI 316L; Residual stress

LIFETIME OF TITANIUM ALLOYS UNDER CONSECUTIVE DYNAMIC AND VERY-HIGH-CYCLE FATIGUE LOADS

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Abstract

An experimental and theoretical studies of fracture mechanisms at different structural levels used in the aeronautical alloys (titanium VT-6 and VT-8) were carried based on laboratory experiments with the aim to simulate structural changes and life time of constructions under Foreign Object Damage (FOD) conditions. The dynamic preloading corresponding to FOD conditions was realized for specially designed specimens of titanium alloys using the split Hopkinson (Kolsky) pressure bar. Very-high-cycle (gigacycle) fatigue loading of titanium alloys specimens was carried out on the Shimadzu USF-2000 resonant type testing machine at the asymmetry coefficient $R = -1$ and frequency of 20 kHz under conditions of cooling with compressed air.

Cyclic loading under these conditions revealed a significant decrease in fatigue life in VHCF tests at the critical number of cycles ranging from $2.23 \cdot 10^9$ in the initial (non-deformed) state of the VT-8 alloy specimens to $6.38 \cdot 10^3$ cycles for the preloaded specimen at a stress level of 585 MPa.

It has been found that the fatigue failure stress of the preloaded VT-6 titanium alloy decreases from the stress level of 460 MPa to 130 MPa, which corresponds to the critical number of cycles $\sim 10^8$. Experimental study of fatigue failure in the transient range of high cycle and VHCF (number of cycle $N \sim 10^6$ - 10^8) allowed one to establish the regular decrease of the fatigue failure stress for dynamically preloaded specimens and the existence of the fatigue limit ~ 130 MPa.

The fatigue limit reflects the tolerance ability of preloaded material to stochastic impact actions that are characteristic for aviation motor blades in the FOD conditions that could be used in the service inspections. This conclusion must be supported by the comparative structural studies of the preloaded and native specimens to qualify the failure precursors under blade inspection.

The New View 5010 high-resolution interferometer profiler was used as an effective tool for quantitative analysis to establishing the correlations between mechanical properties and scale-invariant characteristics of defect induced structures formed during VHCF loading. The obtained 3D optical images of the macro- and microrelief formed on the fracture surface of titanium specimens as a result of loading were studied using the fractal analysis technique to establish structural invariants responsible for the characteristic stages of crack advance.

Keywords: Very-high-cycle fatigue; foreign object damage; fractal analysis

Acknowledgements

The work was carried out as part of a major scientific project funded by the Ministry of Science and Higher Education of the Russian Federation (Agreement No. 075-15-2024-535 dated 23 April 2024).

EFFECT OF THE LASER SHOCK PEENING AREA LOCATION ON THE FATIGUE PROPERTIES OF SPECIMENS WITH STRESS CONCENTRATORS

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Abstract

Laser shock peening (LSP) is a potentially promising technique for surface hardening of metals, which can significantly increase fatigue life by creating residual compressive stresses in the material. The relevance of this method is driven by the growing requirements for reliability and durability of critical components in the aerospace and mechanical engineering industries. The efficiency of LSP depends on a wide range of technological parameters: laser pulse energy, number of passes, spot shape and other process characteristics. One of the key, but insufficiently studied, factors influencing the effectiveness of LSP is the spatial arrangement of the treatment area.

In order to investigate this factor, this experimental research was performed. The processing was carried out using a Beamtech SGR-Extra-10 solid-state Nd:YAG laser with a pulse energy of 3 J, a square spot of 1 mm side, and without overlap. Aluminum foil with a thickness of 80 microns was used as a protective coating. Two types of flat specimens with a thickness of 4 mm were tested: with a lateral V-shaped notch made of titanium alloy VT1-0, and with a lateral semicircular notch made of titanium alloy OT4-0. Two LSP scheme were realized to find optimal conditions for improvement of fatigue properties. The first scheme assumed positioning the LSP zone at a distance of 1.5 mm from the notch tip, while the second scheme involved treatment around the stress concentrator. The specimens were subjected to sequential laser shock peening on both sides. After LSP residual stresses were determined at the center of both zones using an automated MTS3000-Restan system by the hole drilling technique in accordance with ASTM E837 standard. Fatigue tests were conducted on a 100 kN Bi-00-100 servo-hydraulic testing machine under constant amplitude loading with a stress ratio of $R = 0.1$. During fatigue testing, the crack length was measured using the potential drop method.

Based on the obtained results, it was concluded that laser treatment applied at a distance from the stress concentrator reduces the fatigue performance of specimens by 30%, whereas positioning the treatment zone around the concentrator doubles the fatigue life.

Keywords: Fatigue life; laser shock peening; residual stress; stress concentrators

Acknowledgement

The work was carried out as part of a major scientific project (Agreement No. 075-15-2024-535 dated 23 April 2024).

ULTRA-LOW CYCLE FATIGUE ANALYSIS OF A LOW-DAMAGE FRICTION STEEL CONNECTION

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Abstract

This study focuses on the Sliding Hinge Joint (SHJ), a type of friction connection designed for use in moment-resisting steel frames. The beam is connected to the column via top, bottom, and web plates, which are welded to the column flange. The connection's energy dissipation relies on friction within its Asymmetric Friction Connections (AFCs), where high-strength bolts clamp friction shims, located on the bottom and web plates. For seismic demand corresponding to the design-level earthquake, only damage in the bolts could be registered. Therefore, to restore the functionality of the connection, the bolts shall be replaced if required. To assess the susceptibility to fatigue of the bottom plate, advanced numerical analyses of a joint sub-assembly are carried out using the method developed by Jia, which combines the void growth model and the Miner's rule in an incremental form; the fatigue failure occurs when a damage index reaches a value of one. The sub-assembly is subjected to different amplitudes of chord rotations, and the number of cycles to failure is registered each time. The findings confirm that the current design procedures guarantee the connection's proper performance and that the bottom plate is not susceptible to ultra-low cycle fatigue.

Keywords: Low-damage; friction connections; FE analysis; fatigue; steel structure; seismic design

BIAXIAL FRETTING OF ZIRCONIUM ALLOYS IN HIGH-TEMPERATURE PRESSURIZED WATER: INTERFACIAL MATERIAL TRANSFER AND SUBSTRATE FATIGUE

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Abstract

This study systematically investigates the damage behavior and mechanisms of zirconium alloy (Zr-1Nb) under different fretting modes (sliding wear, impact wear, and impact-sliding wear) in a high-temperature pressurized (HTP) borated-lithiated water environment. Biaxial loading experiments were conducted to simulate real operational conditions of fuel cladding tubes in pressurized water reactors (PWRs). Multi-scale techniques including real-time hysteresis loop analysis, 3D morphology characterization, scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), and electron backscatter diffraction (EBSD) were employed to reveal the critical roles of interfacial material transfer and substrate fatigue in damage evolution. Results demonstrate a significant nonlinear synergistic effect under impact-sliding wear: wear volumes at 50 μm and 100 μm displacement amplitudes were three and seven times greater, respectively, than the sum of individual mode effects. Impact loading primarily induced substrate plastic deformation and fatigue crack propagation, while sliding wear caused surface spalling and debris accumulation. Their coupling accelerated material degradation, leading to a composite failure mode characterized by "surface spallation-substrate cracking." Material transfer from the Zr alloy to the counterbody under dynamic loading further exacerbated interfacial damage. Additionally, HTP water penetrated the substrate through crack networks, triggering oxidation and corrosion. This study provides important theoretical insights for lifespan prediction and safety design of zirconium alloys in extreme nuclear reactor environments.

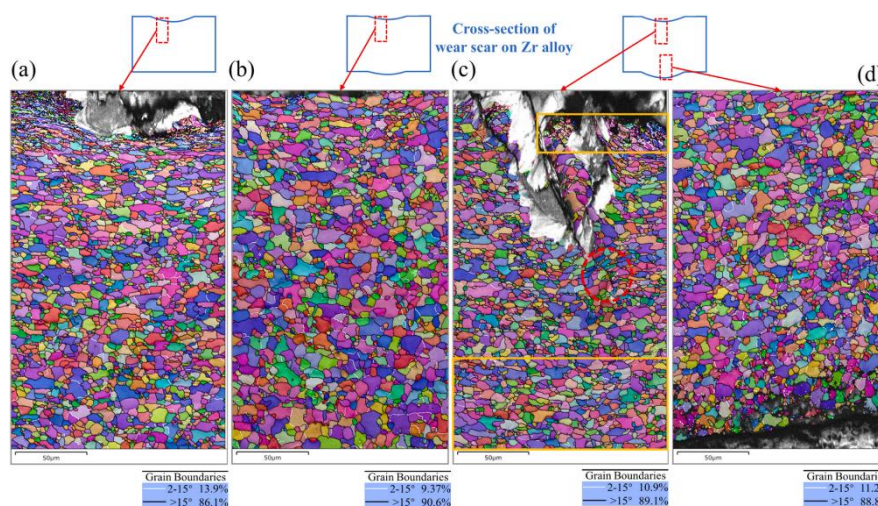


Fig. 1 Cross-sectional EBSD for sliding wear, impact wear, impact-sliding wear

Keywords: Impact-sliding wear; Zr alloys; Fatigue crack; Material transfer

FATIGUE BEHAVIOR OF MINIATURIZED 316L LATTICE SPECIMENS MANUFACTURED BY L-PBF: INFLUENCE OF BUILD ORIENTATION AND STRESS RATIO

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Abstract

In recent years, the fatigue behavior of architected materials has attracted increasing attention, as their industrial adoption requires reliable life prediction methods. However, a gap persists between the potential benefits of metamaterials and the ability to accurately estimate the fatigue life of lattice structures. These components are commonly produced by additive manufacturing, with Laser Powder Bed Fusion (L-PBF) being one of the most adopted. While highly versatile, L-PBF introduces manufacturing-induced defects, such as internal porosity and high surface roughness caused by partially melted powder particles. These features serve as preferential sites for crack initiation and propagation, significantly affecting fatigue performance.

The occurrence and severity of these defects depend on the build orientation and interact differently with the applied load conditions. To investigate these effects cost-effectively, miniaturized thin-strut specimens in 316L stainless steel were manufactured in three orientations: 30°, 45°, and 90° relative to the building plane. The specimens underwent detailed metrological analysis to characterize defects, followed by fatigue tests under different stress ratios: $R = 0.1$ (tensile-tensile), $R = -1$ (fully reversed), and $R = -4$ (compressive-dominant). Results were presented in Haigh diagrams, showing the relationship between fatigue strength and mean stress.

This approach offers a practical way to reduce testing costs while providing essential insights into how manufacturing-induced defects and stress ratios influence fatigue behavior. The findings contribute to a deeper understanding of 316L L-PBF components, supporting the development of predictive models and design guidelines for industrial applications.

Keywords: Laser-Power Bed Fusion; fatigue analysis; 316L; miniaturized specimens; lattice structures.

Acknowledgement

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INFLUENCE OF LOAD RATIO ON FATIGUE CRACK PROPAGATION IN ADDITIVELY MANUFACTURED Ti6Al4V CT SPECIMENS

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Abstract

Additively manufactured (AM) alloys are becoming increasingly prevalent in high-performance applications, but their fatigue behavior, a crucial factor for structural integrity, is still not fully understood. This study investigates the influence of the load ratio (R) on fatigue crack propagation in Ti-6Al-4V specimens produced by laser powder bed fusion (L-PBF). We conducted fatigue crack growth tests on compact tension (CT – ASTM E647 standard) specimens under three distinct load ratios: $R=0.10$, $R=0.50$, and $R=0.75$. The results show a clear dependency of the crack propagation rate on the load ratio, with higher R values leading to an accelerated crack growth. This can be attributed to the reduced crack closure effect at higher mean stresses. Fracture surface analysis using a scanning electron microscope (SEM) revealed the underlying micromechanisms of fracture (Figure 1). We observed a transition from a faceted, quasi-cleavage fracture mode at low load ratios to a more ductile, striation-based mechanism at higher load ratios. This research provides valuable insights into the fatigue performance of AM Ti-6Al-4V, which is essential for its reliable use in critical applications..

Keywords: Additive manufacturing; fatigue; damage; defects

Acknowledgement

This research was made possible with funding from the European Union – Next Generation EU, Mission 4 Component 1, which was administered through the Italian Ministry of University and Research as part of the PRIN 2022 program. The unique project code (CUP) for this work is H53D23001200006.

INFLUENCE OF LASER SHOCK PEENING ON KINETIC OF FATIGUE CRACK PROPAGATION

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Abstract

Creation of compressive residual stresses in the surface layer of the part retards initiation and propagation of fatigue cracks. This effect is the fundamental basis for various surface hardening techniques for parts and structures. One modern methods for inducing significant residual compressive stresses in metals to depths exceeding 1 mm is laser shock peening (LSP). The advantages of this technique include the absence of tool contact with the workpiece and the capability for localized processing of specific areas on components with complex geometries. This method utilizes a high-power nanosecond pulsed laser.

The study of fatigue crack propagation was performed on flat specimens fabricated from Ti64 titanium alloy, with a thickness of 3 mm and featuring a round side notch (radius 8 mm) to localize the site of fatigue crack initiation. Laser treatment was performed using a Beamtech SGR-Extra-10 solid-state Nd:YAG laser. Fatigue properties were studied on a 100 kN Bi-00-100 servohydraulic testing machine under uniaxial cyclic tension with a stress ratio $R=0.1$ and a constant load amplitude. Crack length was monitored employing the electric potential drop method. The specimen surface of ahead of the stress concentrator and the concentrator itself were subjected to laser shock peening. The depth profile of residual stresses was determined by hole-drilling strain-gage method in accordance with the ASTM E837-20 standard. Several laser shock peening modes were selected to study their influence on the residual stress profile and the number of loading cycles to failure. The varied parameters across the studied processing modes included laser beam energy, laser beam profile shape, imprint overlap ratio, and the location of the treated area. An optimal processing regime for flat specimens with stress concentrators was identified. Fatigue testing demonstrated an increase in service life by a factor of up to 8.

Based on the research results, it is concluded that laser shock peening enhances service life primarily by extending the fatigue crack initiation phase. Conversely, once a crack has nucleated, its propagation rate exhibits low sensitivity to the introduced residual stress field.

Keywords: Fatigue crack; laser shock peening; residual stress

Acknowledgement

The study was made in the framework of the government task, registration number of the theme 124020700047-3.

ANISOTROPY IN LCF PROPERTY AND RELIABILITY OF PBF-LB/M 316L STAINLESS STEEL

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Abstract

Metal powder bed fusion-laser beam (PBF-LB/M) 316L stainless steel exhibits anisotropic mechanical properties critical for nuclear components subjected to high-temperature low cycle fatigue (LCF). This study systematically investigates anisotropy in microstructure, mechanical response, LCF properties, and fatigue reliability through microstructural characterization, nano-indentation, tensile tests, and strain-controlled LCF tests (550 °C, 0.3–1.0 % strain amplitude). The melting pool, grain morphology, and lack-of-fusion defects exhibit distinct anisotropic features. The anisotropy in tensile and LCF properties of PBF-LB/M 316L is primarily attributed to $\langle 110 \rangle \parallel \text{BD}$ texture and differences in the projected area of lack-of-fusion defects. And, the high-reliability LCF properties ($N_{95\%}$) of different orientated PBF-LB/M 316L are compared with traditional 316L, yielding the following ranking: traditional 316L > horizontal PBF-LB/M 316L > vertical PBF-LB/M 316L. Both the anisotropy in PBF-LB/M 316L fatigue reliability and the difference between PBF-LB/M and traditional 316L gradually decreased with the increasing strain amplitude.

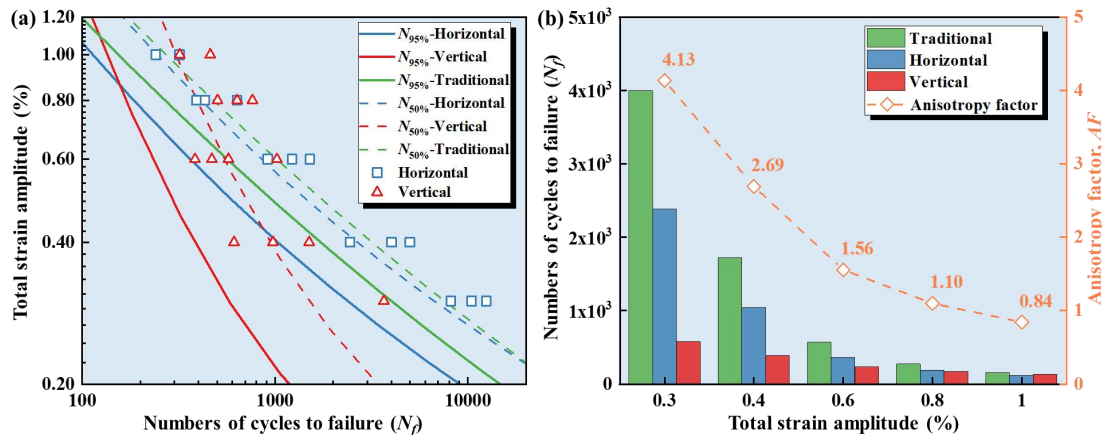


Figure. 1 (a) Comparison in $N_{95\%}$ and $N_{5\%}$ curves between horizontal, vertical, and traditional specimens; (b) $N_{95\%}$ columns and AFs at various total strain amplitudes.

Keywords: PBF-LB/M; Low cycle fatigue; Reliability; High temperature; Anisotropy

CREEP AND CREEP CRACK GROWTH OF ADDITIVELY MANUFACTURED 316L STAINLESS STEEL: AN INTEGRATED EXPERIMENTAL AND SIMULATION STUDY

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Abstract

Additive manufacturing technology has garnered significant attention in recent years due to its near-net-shaping capability and high design freedom. In light of the current lack of long-term creep data and insufficient research on creep fracture mechanisms for AM 316L, this study conducted high-temperature creep tests on as-printed and recrystallized 316L samples. Combined with microstructural characterization, the influence of the printed microstructure on creep deformation behavior was revealed. High-temperature creep crack propagation tests further demonstrated anisotropic growth rates in the material, while transgranular isotropic propagation occurred under high stress. Finite element simulations based on the Wen-Tu model successfully predicted the creep crack propagation behavior. This study clarifies that the high-temperature performance of LPBF 316L is governed by the synergistic effect of dislocation structures and grain boundary morphology, providing a theoretical basis for optimizing its long-term high-temperature service performance.

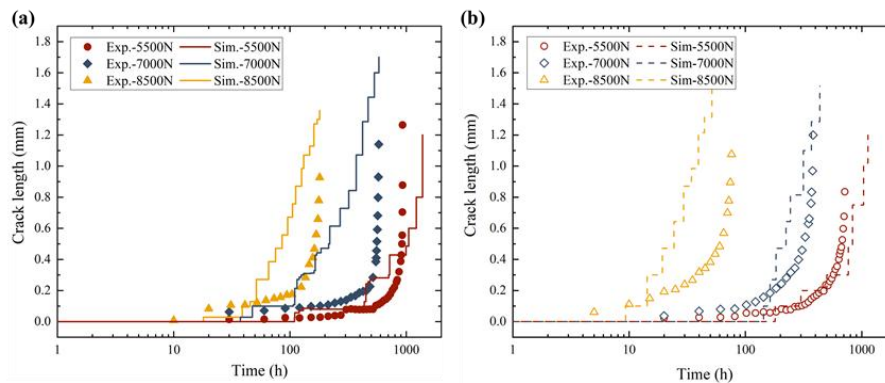


Figure 1. Comparisons of creep crack length between the FE simulations and experimental results for LPBF 316L at 600°C: (a) in the Z-X orientation (b) in the X-Z orientation

Keywords: Additive Manufacturing; Creep; Creep Crack Growth; Finite Element Analysis

Acknowledgement

The authors are grateful for the supports provided by the National Natural Science Foundation of China (52475156), the National Key Research and Development Program of China (2024YFF0618904) and the Shanghai Gaofeng Project for University Academic Program Development.

REMAINING LIFE OF A SPHERICAL TANK IN PRESENCE OF CRACKS

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Abstract

Cracks were found during regular NDT examination in a large spherical tank, made of low carbon high quality steel with yield strength 385 MPa, similar to A516 Gr.60. Length of cracks was between 5 and 150 mm, with depth up to 13.8 mm, more than half of the vessel thickness (26 mm). In order to assess their influence on structural integrity, remaining life of spherical tank with initial crack depth 1.9 mm was estimated using Paris law. Standard testing of welded joint were performed to obtain coefficients C and m for all three zones – C = $8.62 \cdot 10^{-9}$, m = 2.92 for base metal (BM), $7.06 \cdot 10^{-9}$, m = 3.26 for weld metal (WM) and C = $7.88 \cdot 10^{-9}$, m = 3.11 for heat-affected-zone (HAZ). Using these values and stress range = 95 MPa, the lowest remaining life for crack growth from the initial value 1.9 mm to the critical value 17.4 mm was for WM (26.4 years), which is reasonably long period of time. Anyhow, if the maximum detected crack depth 13.8 mm is taken as the initial value, then remaining life reduces to 3.5 years, even if the critical depth is taken as 25 mm.

Keywords: large spherical tank; remaining life; welded joint; Paris law; surface cracks

RESISTANCE TO FATIGUE CRACK INITIATION AND PROPAGATION IN HARDFACED LAYERS OF HOT-WORK TOOL STEELS

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Abstract

This study examines the feasibility of using welding as a repair method for damaged components in the forging industry. Critical parts in forging applications are typically made of high-quality hot work tool steels capable of withstanding rigorous impact loads and temperature shocks during operation. These include forging dies, ejectors, inserts, and similar components. Although these steels exhibit excellent mechanical properties, even at elevated temperatures, prolonged use leads to surface damage such as wear on die radii, cracks, or even metal spalling. The cracks that develop on the surface of forging tools are fatigue-induced, resulting from cyclic loading during operation. Once these defects appear, they lead to the stop of production process, necessitating either replacement or repair. Welding repair (hardfacing) is a cost-effective alternative to complete replacement, but the fatigue resistance of the repaired zones must be evaluated. The objective of this study is to assess the fatigue characteristics of hardfaced layers in hot work tool steels used in the forging industry and compare them with the base material's fatigue properties. A defined welding procedure was applied to prepare hardfaced samples, from which test specimens were extracted for three-point bending crack growth testing. Additionally, hardness and microstructural analyses were conducted on the hardfaced layers and heat-affected zone (HAZ). Based on the results, conclusions were drawn regarding the suitability of welding for repairing forging tools.

Keywords: hot work tool steel; forging tool; fatigue crack; hardfacing

Acknowledgement

Authors thank to company Zastava Kovačnica Ltd, Kragujevac, Serbia, for providing the necessary materials and preparation of samples.

A CRYSTAL PLASTICITY-BASED MACHINE LEARNING MODEL FOR EVALUATING SUBSURFACE MICROSTRUCTURE DAMAGE UNDER ROLLING CONTACT FATIGUE

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Abstract

Bearings undergo significant microstructural damage under rolling contact fatigue (RCF). One of the primary damage modes is the subsurface white etching areas (WEA). Although crystal plasticity finite element method (CPFEM) enables modeling the microscale behavior WEA, it cannot fully capture the complexities caused by the position, size, and shape of inclusions that influence WEA. This study develops a new method combining CPFEM and machine learning (ML) models to predict the butterfly WEA formation at non-metallic inclusions in bearing steel. The XGBoost algorithm and SMOTE-NC algorithm were employed to address missing data and augment the dataset, respectively. The number of cycles was identified as the most influential factor in the butterfly WEA formation, followed by depth, diameter, and shape of the non-metallic inclusions. The simulation is in good agreement with experimental data. It revealed a strong correlation between inclusion characteristics and WEA formation: the highest prediction accuracy of 98.80% is achieved with the WEA at 0–100 μm depth range and rhomboid inclusions achieve the highest prediction accuracy of 98.62%. The results showed that the CPFEM-based ML model can successfully simulate the butterfly WEA damage.

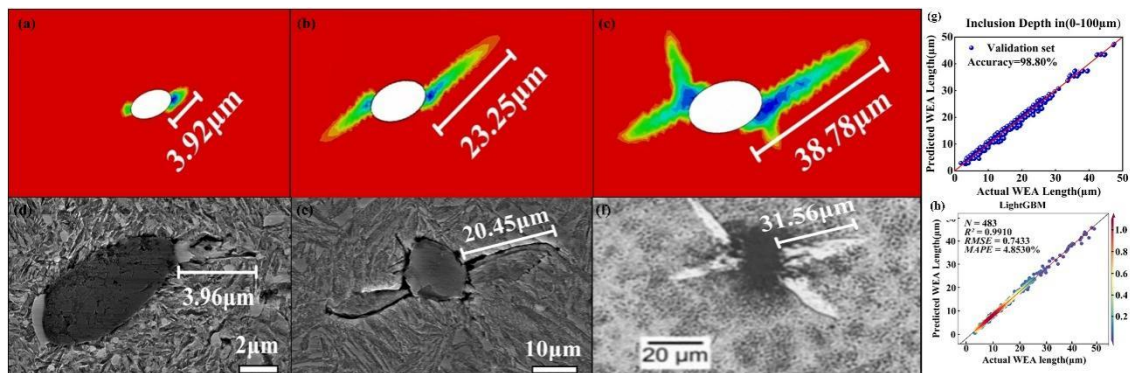


Figure 1. WEA formation by CPFEM-based ML model

Keywords: Rolling contact fatigue; Microstructural damage; White etching area; Crystal plasticity model; Machine learning

Acknowledgement

This work was financially supported by Ningbo Key Technologies R & D Programme (2025Z006) Natural Science Foundation of China NSFC (No. 52075271).

LOW TEMPERATURE BEHAVIOUR OF A516 GR. 60 STEEL WELDED JOINTS UNDER IMPACT LOADING

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Abstract

This paper presents the results of a research performed on welded joints made of steel A516 Gr. 60, focused on its low temperature behaviour under impact loading. The experimental work included impact testing of specimens, taken from all three different zones (base metal, weld metal and heat-affected-zone), on the instrumented Charpy pendulum with the option to separate crack initiation and crack propagation energies and to evaluate percent of ductile fracture. Testing was performed at the room temperature, as well as at lower temperatures, 0, -20, -40 and -60°C. Results indicated satisfying values of total energies of all 3 zones of welded joints with relatively small differences between them. In respect to the separation of energies, all 3 zones indicated higher resistance to crack initiation than to crack growth at low temperatures, and vice versa at temperatures above 0°C.

Keywords: A516 Gr. 60 steel; impact loading; welded joint region; low temperature

RESEARCH ON BULGING DEFORMATION AND CRACKING FAILURE OF LONG-TERM SERVICED CR-MO STEEL COKE DRUMS

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Abstract

Coke drums, as the core reactors in delayed coking units, are prone to fatigue damage and cracking failures due to prolonged exposure to thermomechanical cyclic loading. Over the past two decades, Cr-Mo steel coke drums have gradually replaced carbon steel ones in China due to their superior strength and deformation resistance. However, recently, cracking failures occurred in several Cr-Mo steel coke drums have drawn increasing attention from equipment managers. This study conducted inspections and data collection on several Cr-Mo steel coke drums with varying service years. Laser scanning method was employed to obtain their deformation profiles, and the relationship between bulging deformation, service duration, and cracking severity was analyzed. Through sample testing, the damage characteristics and mechanical properties of long-term service Cr-Mo steel materials were evaluated. The critical influencing factors of thermomechanical fatigue were discussed, including material type, weld performance, and operational processes. The paper also summarized the inspection strategies and proposed the critical bulging deformation thresholds for long-term serviced coke drums. These results provide support for the safety operation of aging Cr-Mo steel coke drums.

Keywords: coke drum; Cr-Mo steel; failure analysis; thermal mechanical fatigue

Acknowledgement

This work is financially supported by the National Key Research and Development Programs of China (2022YFB3306403), the Science and Technology Program of the State Administration for Market Regulation (2024MK215)

CONSECUTIVE SHOCK WAVE AND FATIGUE LOADS: FUNDAMENTALS AND LSP OPTIMIZATION STRATEGY

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Abstract

1.Introduction

Optimization of laser shock-wave forging (LSP) as applied to the processing of materials and structures of aircraft engines involves methodological support for two consequent material loads: the shock-wave, initiated by laser action, and loads simulating the damage staging during operation. Typical loads are fatigue, including conditions of accidental impact with foreign objects.

2.Fundamentals

The fundamentals are the results of original experimental studies and modeling of the behavior of materials under consecutive dynamic (shock-wave) and fatigue (HCF and VHCF) loads, which made it possible to establish a links between self-similar patterns of formation of plastic wave fronts, the staging of the nucleation and development of fatigue cracks in loaded samples and scale invariants characterizing the structure of materials that provide different fatigue life depending on the LSP regimes.

The results of original wide-range experiments made it possible to propose models of shock-wave and fatigue failure processes that take into account structural factors and allow optimization of shock-wave forging modes.

3.Methodology

The methodological support for monitoring LSP modes is based on measuring the parameters of the laser induced shock-wave pulse on model (plate) target samples by the Doppler interferometry method using the original VISAR-PDV set-up and data processing in order to determine the invariants characterizing the formation of self-similar plastic fronts and the corresponding structure of the material formed during the propagation of the shock-wave pulse. The subsequent state of the target material subjected to LSP is studied in the HCF or VHCF loading mode, including the stage of nucleation, propagation of a fatigue crack and separation of the sample with subsequent quantitative analysis of the morphology of the fracture surface by the method of interference profilometry and determination of scale invariants characterizing the stages of nucleation of a fatigue crack and its propagation. By comparing shock-wave loading data in terms of energy invariants and scale invariants characterizing the stages of fatigue failure, optimal conditions for laser processing are determined, ensuring the required in-service life of aircraft engine constructions.

Keywords: Shock wave; fatigue; LSP optimization

Acknowledgement

Research was supported by the government contract n. 124020200116-1.

LOW CYCLE FATIGUE BEHAVIOR OF Zr-2.5Nb ALLOY: EXPERIMENTAL CHARACTERIZATION AND CRYSTAL PLASTICITY FINITE ELEMENT SIMULATION

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Abstract

Pressure tubes of Zr-2.5Nb alloy in Pressurized Heavy Water Reactors experience low cycle fatigue (LCF) due to cooling water flow and power fluctuations, which could be a structural integrity destroying factor for them. Therefore, it is essential to conduct a systematic investigation into their low cycle fatigue (LCF) properties and to develop accurate life prediction models. This study addressed these gaps by conducting LCF tests on Zr-2.5Nb alloy under strain amplitudes ranging from $\pm 0.50\%$ to $\pm 1.5\%$ at room temperature. The results revealed that the cyclic stress gradually transitioned from initial softening to hardening as the strain amplitude increased, with corresponding microstructural evolution. A novel fatigue life prediction model based on plastic work of back stress was proposed. For non-Masing materials, the proposed model overcame the limitations of traditional plastic strain energy models and demonstrated higher prediction accuracy. Besides, the LCF behavior was simulated based on the crystal plasticity finite element method (CPFEM). Plastic strain accumulation (PSA) and energy dissipation were used as fatigue indicator parameters (FIP) to predict fatigue damage and life. Both of the two FIPs can effectively predict fatigue life. Fatigue deformation tends to occur at the α/β and α/α interfaces, resulting in the initiation of fatigue cracks. This work contributes to a more accurate prediction of fatigue life in Zr alloys and provides new insights into their fatigue behavior and microstructure evolution under LCF conditions.

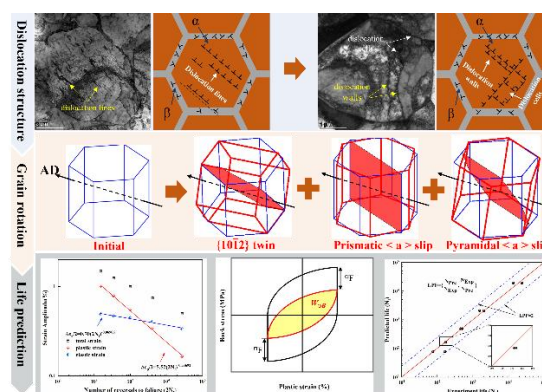


Figure 1. Graphical abstract

Keywords: Zr-2.5Nb alloy; Low cycle fatigue; Microstructure evolution; CPFEM; Life prediction

Acknowledgement

This study was supported by the National Natural Science Foundation of China (Grant Nos. 52275161).

ENHANCED FATIGUE RESISTANCE AND FATIGUE-INDUCED SUBSTRUCTURES IN AN ADDITIVELY MANUFACTURED COCRNI MEDIUM-ENTROPY ALLOY TREATED BY ULTRASONIC SURFACE ROLLING PROCESS

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Abstract

There is a significant need to elucidate the underlying mechanisms of cyclic plastic damage in additively manufactured materials and develop effective surface modification techniques to improve their fatigue life. This study investigates the efficacy of the ultrasonic surface rolling process (USRP) technology in the creation of a $\sim 300\ \mu\text{m}$ gradient nanotwinned structure on the surface of additively manufactured CoCrNi medium-entropy alloy (AM-MEA), which results in a beneficial result that yield strength and 107-cycle fatigue endurance limit are significantly improved, achieving the increment of 192.1 MPa and ~ 130 MPa, respectively. The superior fatigue property is attributed to multiple factors that suppress crack initiation from sample surfaces jointly, including the presence of a gradient nanotwinned layer and the reduction in irregular defects located both on and beneath the surface. The cyclic plastic deformation behavior of AM-MEA samples with and without USRP under both high and low stress levels was studied in-depth through multiscale characterization techniques. When exposed to cyclic loading at a low stress level of 480 MPa, the fatigue damages of both samples were dominated by accumulation of statistical stored dislocations (SSDs) and persistent Lüders bands. There is no significant difference in the increase in dislocation density between both samples. However, under cyclic loading at a high stress level of 660 MPa, the fatigue damage of the AM-MEA sample primarily originated from the accumulation of deformation nanotwins, stacking faults, geometrically necessary dislocations and SSDs. Conversely, the fatigue damage observed in the AM-MEA sample with USRP at the same stress level was dominated by an increase in stacking faults and SSDs. Notably, this increase in total dislocation density was visibly lower than that observed in the AM-MEA sample, which is ascribed to the stable gradient layer providing enhanced hetero-deformation induced stress for the core region in the AM-MEA sample with USRP at high stress level.

Keywords: Additive manufacturing; Medium-entropy alloys; Ultrasonic surface rolling process; Fatigue-induced substructures; Fatigue enhancement mechanism

Acknowledgement

This work was financially supported by the National key research and development program (2022YFB4602100), National Natural Science Foundation of China (Nos. 52205152, No. 51725503, No. U21B2077), Shanghai Super Postdoctoral Incentive Plan (No. 2021103).

CONSERVATIVE VARIANT OF TWO-STEP-SCALING MODELING OF FRACTURE TOUGHNESS SIZE EFFECT

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Abstract

This study explores a conservative approach to the two-step-scaling (2SS) method developed recently to predict the fracture toughness (K_{Jc}) of ferritic steels in the ductile-brittle transition (DBT) region in the form of cumulative distribution function (CDF). The empirical 2SS method is based on using the most accurate fit of input experimental datasets, assumed to exhibit weakest link behavior. Consequently, the data-driven 2SS CFD (K_{Jc}) predictions reflect the maximum likelihood behavior, given well-behaved experimental datasets. Recognizing the inherent aleatory variability (“irreducible” uncertainty) of fracture toughness in the DBT region and the need for engineering safety and preservation of structural integrity, it is crucial to provide CDF (K_{Jc}) predictions that include a pre-determined level of conservatism to ensure safe design practices. The current approach recommends reducing the Weibull shape and scale parameters by a specified factor ($0 < \chi \leq 1$) to ensure the CDF shifts in a conservative direction as illustrated in Figure 1.

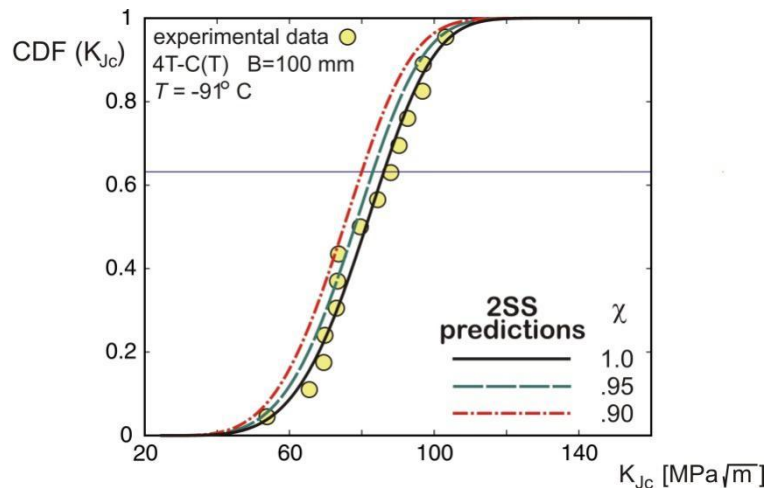


Figure 1. Experimental CDF (K_{Jc}) for 22NiMoCr37 ferritic steel with 2SS predictions corresponding to three different values of the reduction factor χ

Keywords: Fracture toughness; ferritic steels; brittle-ductile transition; size effect; scaling

Acknowledgement

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

INTEGRITY AND LIFE ASSESSMENT OF A SUPERDUPLEX STAINLESS STEEL WELDED JOINT

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Abstract

The effect of variable loads on integrity and life assessment of welded joints made of superduplex stainless steel S32750 was analysed using fatigue crack growth parameters. Standard tests of welded joints were conducted for the purpose of obtaining the values of coefficients C and m for all three welded joint regions - $C = 4 \cdot 10^{-4}$, $m = 3.67$ for the base metal (BM), $C = 1 \cdot 10^{-7}$, $m = 6.07$ for the weld metal (WM) and $C = 7.7 \cdot 10^{-2}$, $m = 2.36$ for the heat affected zone (HAZ). Based on the obtained Paris equation parameters C and m , remaining life assessment in terms of cycles was calculated using the following formula:

$$\Delta N = \frac{l}{C [Y \Delta \sigma \sqrt{a}]^m} \cdot \frac{a_0^{\left(1 - \frac{m}{2}\right)} - a_d^{\left(1 - \frac{m}{2}\right)}}{\frac{m}{2} - 1}$$

For this analyses, the following values for initial and critical crack length (respectively) have been adopted - $a_0 = 1$ mm and $a_c = 5$ mm, whereas $\Delta \sigma$ was varied between 15 MPa, 20 MPa and 25 MPa, i.e. the analysis used different load ranges. Initial crack length corresponds to the minimum value which can be detected using Non-destructive test methods (NDT), while critical crack length represents an arbitrary choice. Obtained results indicated that there was a significant drop in remaining life for the WM and the HAZ (where it was particularly prominent), compared to the BM, in terms of the number of cycles. This implies that the heat affected zone has the most adverse effect on the assessed remaining life of a welded joint made of superduplex steel.

Keywords: Superduplex stainless steel S32750; welded joint; Paris law; fatigue crack growth; remaining life

FRACTOGRAPHY ANALYSIS OF DUPLEX STEEL WELDMENTS BEHAVIOUR UNDER IMPACT LOADING

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Abstract

This paper presents the fractography analysis of duplex steel weldments behaviour under impact loading. Experiments were performed using welded joints made of duplex steel S32750 by testing them on the Charpy instrumented pendulum, enabling separation of total energy into crack initiation, E_i , and crack propagation energy, E_p . Testing was conducted in accordance with standard EN ISO 148-1:2017 at different temperatures: +20°C, -40°C, -60°C and -80°C. Fractography was done to clarify fracture behaviour of welded joints made of duplex steel S32750 under impact loading and different temperatures. Fractography indicated substantial plastic deformation in BM even at -80°C, both at initiation and at final fracture. Homogeneous distribution of dimples, about 10 μm in diameter, with corresponding voids resulted in ductile fracture by coalescence mechanism. Weld metal features mixed, quasi - cleavage mode fracture with fine dimples, 2-3 μm in diameter and cleavage morphology. Comparison between initiation and final fracture, shows no growth of dimples. It implies that fracture starts in ductile mode and finishes with cleavage. In HAZ area, however, transgranular cleavage dominates fracture mechanism. It is an effect of brittle intermetallic precipitation in the temperature range 750 to 1000°C. Delamination was also presented, more pronounced at lower temperatures (-60°C and -80°C). Typically, it initiated at the notch tip and grow perpendicular to the main crack.

Keywords: Duplex steel; fractography; transgranular cleavage; impact loading

FRACTOGRAPHIC ANALYSIS OF HADFIELD CAST STEEL EXPOSED TO IMPACT LOADING

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Abstract

Fractographic analysis of Hadfield cast steel exposed to impact loading is performed. Two sets of hammer tools made of high manganese austenitic Hadfield steels (one with 12%Mn/1.2%C, the other with 16%Mn, 1.1%C/1.9%Cr/0.20%Mo) were examined in as-casted and water quenched state after 1/4, 2/4, 3/4 and 4/4 of time of exploitation. The aim of this analysis was to study and explain deeper strain hardening behaviour of Hadfield cast steel as affected by different chemical composition, heat treatment and time of exploitation. Focus of this analysis was on the role of carbides in respect to their location and size, keeping in mind the effect of heat treatment, Fig. 1.

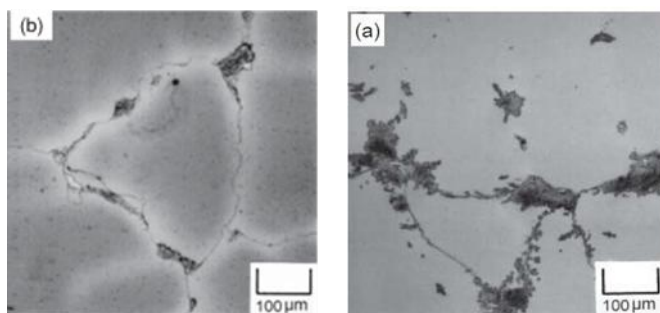


Figure 1. Microstructure with carbides on grain boundaries: (a) as-cast (b) after heat treatment

Keywords: Hadfield cast steel; Impact loading; heat treatment; time of exploitation

STUDY ON THE DEGRADATION MECHANISM OF MECHANICAL PROPERTIES OF CARBON-GLASS HYBRID COMPOSITES UNDER HYGROTHERMAL CONDITIONS

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Abstract

With the increasing application of carbon-glass hybrid fiber-reinforced polymer (C/GFRP) composites in aerospace and other fields, their durability in hygrothermal environments has become a critical issue limiting their reliable service. This paper systematically investigates the hygrothermal aging behavior of C/GFRP laminates in 80°C deionized water. Water bath aging experiments were conducted, with tensile and shear tests performed on laminates at 0, 6, 12, 18, 24, 30, and 36 days of aging, and scanning electron microscopy (SEM) was used to observe the fracture morphology. A finite element model for moisture diffusion was established, and a user material subroutine (VUMAT) considering the influence of moisture concentration was developed to simulate the degradation of mechanical properties. The results indicate that the material reached moisture absorption saturation after 36 days, with a saturation moisture uptake of approximately 1.17%. Hygrothermal aging significantly affected both the strength and modulus of the material, after saturation, the tensile and shear strengths decreased by approximately 37% and 24%, respectively, while the moduli decreased by about 8.8% and 38%, respectively. Notably, the modulus reduction exhibited a unique staged characteristic, a sharp decrease in tensile modulus (2.31%) occurred during the later stage of aging (24-30 days), whereas the shear modulus experienced a drastic drop (28.44%) early in the aging process (0-6 days). The moisture diffusion model revealed that water molecules diffuse from the surface to the interior of the material, with a higher diffusion rate in the GFRP layers compared to the CFRP layers. The mechanical model based on this successfully predicted the displacement-load response. Fractography analysis showed that with prolonged aging, the tensile fracture surfaces exhibited increased fiber debonding and a significant reduction in resin adhesion on pulled-out fibers, while the shear fracture surfaces were dominated by interlayer delamination and severe fiber-resin interface failure. This research systematically reveals the hygrothermal aging mechanism of C/GFRP from experimental testing, numerical simulation, and micro-mechanistic perspectives, providing theoretical and experimental support for the long-term performance evaluation and prediction of C/GFRP in hygrothermal environments.

Keywords: Hybrid fiber laminates; Hygrothermal aging; Mechanical properties; Finite element method; Failure mechanism

FRACTURE OF ROCKS UNDER EXTREME CONDITIONS

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Abstract

The pre-fracturing state of rocks (as a result of explosive impact) is the initial stage of the evolution of the internal microstructure of geomaterials. At this stage, deformation and reorientation of individual grains, disruption of bonds, development of microdefects, and changes in the properties and state of a certain volume of the medium occur. Wave pre-fracture of rocks plays an important role, for example, in preserving precious crystals (for example, diamond crystals) during explosive disintegration of rocks or in predicting man-made changes in the filtration characteristics of a rock mass. Wave prefracturing facilitates rock fragmentation to a standard quality size. This article discusses conditions of induced microcracking in the zone of wave prefracturing of solid rock due to blast wave. The prefracturing zone under confined (camouflet) explosion, for example, under conditions of cylindrical symmetry can expand to 100 and more radii of explosive charge. It is of great scientific interest to compare results from studying the effect different kinds of energy impacts have on the formation and parameters of microdefects in geomaterials with different structural and chemical, electrophysical, and physicochemical properties. Comparing results obtained in this work and the experimental data on the formation of microcrack systems in rocks under nonthermal effect of high-power nanosecond electromagnetic impulses (HPEMP), we established that the minimum value of the microcracks opening in rocks after explosive impact and HPEMP effects is $\sim 0.1\text{--}0.5\text{ }\mu\text{m}$, and the most typical opening width is $2\text{--}3\text{ }\mu\text{m}$. Scanning electron microscopy (SEM, JSM-6610 LV) data show that most of the microcracks which appear in rocks after the impact of high pulse pressure from explosions and treatment with HPEMP are of the Mode I type (i.e. crack causes the crack to open orthogonal to the local fracture surface). No shear-type formation of defects was observed. Under explosive action, the newly formed cracks propagated inside the grain boundaries in the rocks (the character of disintegration was primarily transcrystalline, Fig.1a). Under the impact of HPEMP, the trajectory of microcrack propagation for coal was affected by the presence of microinclusions. The formation of microcracks in sandstone and granite was recorded primarily along grain boundaries (intercrystalline fracture, Fig.1b), which determines the selective disintegration of ores effect exposed to HPEMP.

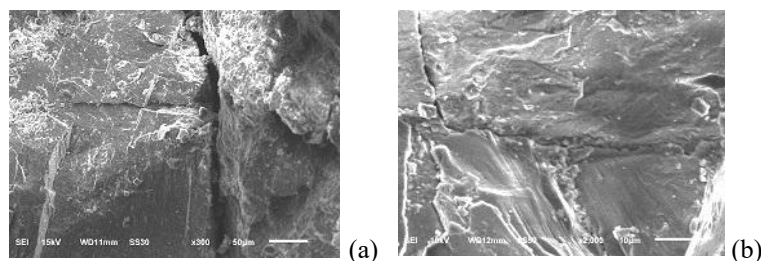


Figure 1. Formation of microcracks in a granite samples when exposed to (a) explosive and (b) HPEMP effects.

Keywords: Rocks; fracture; microcracks; explosive impact, high-power nanosecond pulses

MECHANISMS OF REDUCED TENSILE DUCTILITY IN LPBF INCONEL 718 AT 650°C REVEALED BY EXPERIMENT AND CRYSTAL PLASTICITY

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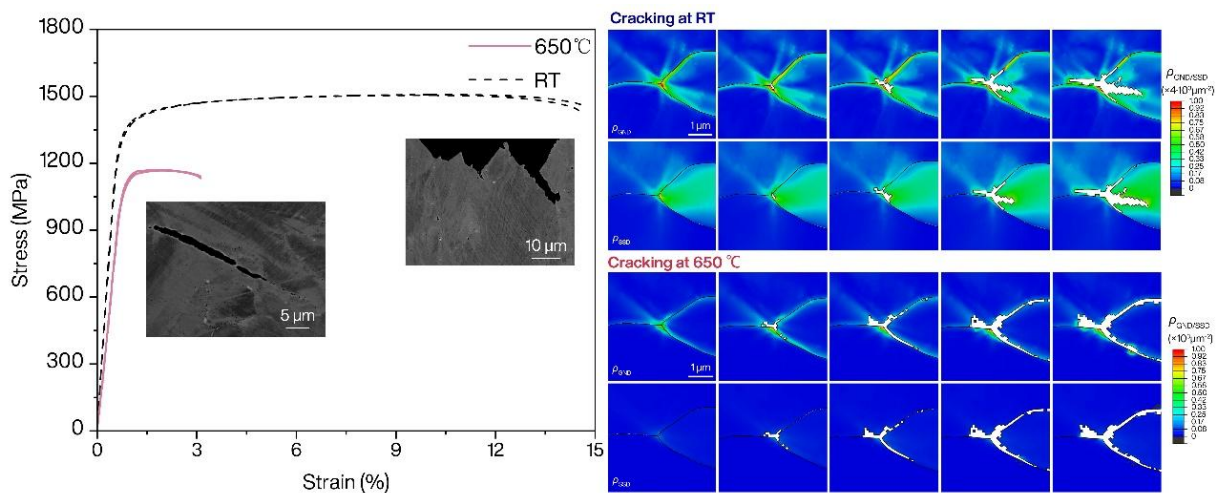
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Abstract

The reduced tensile ductility of laser powder bed fused (LPBF) Inconel 718 at high temperatures restricts its application in aerospace and nuclear industries. The cause of the lower ductility at 650 °C compared with room temperature (RT) was quantified and validated by crystal plasticity simulations. Although high strength and appreciable ductility were achieved at RT, tensile performance degraded strongly at 650 °C, with elongation reduced to 21% of the RT value. Microstructural characterization showed partial recrystallization, reducing cellular structures and segregation, although columnar grains remained perpendicular to the build direction. Nb- and Ti-rich MC carbides at grain boundaries further promoted strain localization, facilitating intergranular fracture. A damage evolution model integrated within a crystal plasticity framework, explicitly incorporating geometrically necessary dislocation (GND) and statistically stored dislocation (SSD), reproduced GND-dominated intergranular fracture at 650°C and SSD-dominated transgranular fracture at RT. The results elucidate the temperature-dependent tensile fracture mechanisms in LPBF Inconel 718 and provide a predictive model to support the reliable deployment of additively manufactured superalloys in high-temperature service.



The intergranular cracking at 650°C and transgranular cracking at room temperature

Keywords: Additive manufacturing, Ni-based alloy, Microstructure, Ductility, High temperature property

Acknowledgement

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DISCRETE APPROACHES TO DYNAMIC FRACTURE PROBLEMS. INERTIA OF THE DYNAMIC FRACTURE PROCESS

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Abstract

The fracture criterion based on the concept of incubation time was used for the analytical study of the dynamic crack onset due short pulse loading. Special attention was paid to the phenomenon of delayed fracture which is a fundamental effect that can be observed in experiments with relatively short threshold pulse loads. The effect can be described in the following way: material failure occurs after local stresses have reached their maximum values, which means that fracture takes place at the decrease stage of the stress fields acting at the considered location. In addition, we discuss a simple analogy between the process of the crack initiation and a linear oscillator failure, which makes it possible to attribute inertia to the fracture process. A fracture model based on a linear oscillator is also proposed and investigated. The model can be used to describe the crack onset due to dynamic loading and to model spallation in steel specimens under pulse load conditions. The model allows one to study the key effects of the dynamic fracture phenomenon – the material strength increase observed for high loading rates and the fracture delay.

Keywords: Dynamic fracture, incubation time, crack initiation, spallation, oscillator, inertia, fracture delay

Acknowledgement

The work was supported by RSF Grant № 22-11-00091II.

EFFECT OF MATERIAL FORMABILITY PARAMETERS AND CUTTING METHOD ON SHEARED-EDGE STRETCHABILITY IN ADVANCED HIGH STRENGTH STEEL SHEETS

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Abstract

The limited local formability of advanced high strength steel (AHSS) results in premature edge cracking during stamping. In this study, the influence of material deformation parameters and cutting method on the edge-stretching capability of AHSS was investigated, and the corresponding microstructural interpretation was provided. Comprehensive hole expansion and uniaxial tensile tests were conducted on DP590, DP980, TRIP980, SPFC440, and DC06 steels using the digital image correlation (DIC) technique, with test-specimen holes manufactured by laser, water jet, and EDM cutting methods. Furthermore, scanning electron microscopy (SEM) and microhardness testing were employed to investigate microstructural crack formation and phase hardness. The results indicate that the DC06 and SPFC440 specimens exhibited hole expansions of approximately 168% and 155%, respectively, whereas the DP590 specimen expanded by only around 103% before crack initiation. Likewise, the hole expansion ratios (HER) of DP980 and TRIP980 were around 53% and 50%, respectively. Moreover, for DP590 steel, a reduction in the HER of 45.5% and 20.4% was observed when laser and water-jet cutting were used, respectively, compared to the EDM method. These findings suggest that a higher strain hardening exponent (n-value) in dual-phase and TRIP steels increases local strength and hardness, reducing edge ductility and promoting premature edge cracking. The pronounced ferrite–martensite hardness difference causes severe dislocation pile-up in ferrite, leading to delamination at their interface. Additionally, it can be stated that the difference in HER between DP980 and TRIP980 steels can be explained by the TRIP effect. Ultimately, the presence of pronounced macro-cracks within the fracture zone of the shear affected zone (SAZ) on the hole surface of the water-jet and laser-cut DP590 specimens contribute to their inferior edge-stretching performance.

Keywords: Hole expansion ratio, Edge crack, AHSS, dual phase steel, TRIP steel

FAILURE ANALYSIS OF A ROLL JOURNAL IN A PAPER MACHINE

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Abstract

The failure of the paper machine upper roll made of 42CrMo4 steel was investigated. The roll journal was previously repaired by weld build-up. The fracture occurred at the roll journal within the bearing shortly after the roll was put into service. The microstructure of the base material and the weld deposit was investigated using light microscopy. The fracture surface was examined using a stereo microscope and a scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectroscopy (EDS). The mechanical properties were examined by measuring Brinell hardness along the line from the center to the surface and the weld deposit. Liquid penetrant testing did not reveal any surface cracks. The hardness of the weld deposit was between 240 and 270 HB, in accordance with the specifications. However, the hardness of the base metal was 194 HB, which was significantly lower than that expected for the annealed 42CrMo4 steel. The microstructure of the base metal consisted of pearlite, grain-boundary ferrite and intragranular ferrite, while the microstructure of the weld metal consisted of fine ferrite grains. The microstructural examination also revealed coarse, elongated cavities at the border between the weld deposit and the base material and smaller rounded cavities between the layers of the weld build-up. Ratchet marks at the fracture surface along the circumference of the roll journal indicated fracture initiation at multiple points near the surface of the roll journal. Examination under a stereo microscope revealed large cracks near the surface and beach marks indicating a fatigue fracture. SEM revealed elongated coarse cavities and large cracks near the fracture initiation sites. EDS analysis revealed traces of calcium and silicon, indicating the formation of the inclusions at the base metal/weld metal interface. At higher magnifications, fatigue striations were detected around the fracture origins. All fracture initiation sites along the roll journal rim were in the vicinity of the fillet radius. It was concluded that the failure of the paper machine roll was caused by the fatigue fracture initiated at the inclusions in the area of increased stress concentration near the roll journal fillet radius.

Keywords: Fractography; fatigue fracture; roll journal failure; 42CrMo4 steel

EFFECT OF SPECIMEN THICKNESS AND SHAPE ON TOUGHNESS

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Abstract

The literature has repeatedly reported that the thickness of cracked specimens has a significant effect on the ductile crack growth resistance, see e.g. in textbooks by Anderson (2005), Broek (1982). In this study, a nonlocal version of the Gurson—Tvergaard-Needleman (GTN) model is used to analyze the effect of specimen thickness on the crack growth resistance curves ($J - R$ curves) of Compact Tension (CT) specimens. Two series of simulations are performed. In the first series, the specimen thickness varies between 1 and 25 mm while the specimen width is kept constant (25 mm). In the second series, the specimen shape is kept constant, and its width varies between 3.125 and 50 mm (homothetic scaling of the specimens). Various model parameters are used to perform the simulations: initial void volume fraction, GTN model parameters q_1 and q_2 , damage nucleation. It is found that the measured toughness ($J_{0.2}$ following ASTM E1820) is not significantly affected by the specimen thickness for homothetic specimens (series 2), while it decreases significantly with increasing thickness for non-homothetic specimens (series 1). A toughness maximum is observed when both growth and nucleation are considered.

Keywords: GTN model; toughness; damage nucleation; void volume fraction

INNOVATIVE NON-DESTRUCTIVE TESTING AND MONITORING TECHNIQUES

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- L.R. Botvina, A.I. Bolotnikov, I.O. Sinev - *Acoustic, magnetic and structural characteristics of cyclic degradation of traditional and additively manufacturing steels*
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WHEN HYDROGEN MEETS GRAIN BOUNDARIES IN NICKEL

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Abstract

Hydrogen embrittlement (HE) critically limits the reliability of structural metals in hydrogen environments. Through atomistic simulations of nickel, we investigate how hydrogen–grain boundary (GB) interactions govern vacancy dynamics and fracture pathways. Hydrogen segregation induces local stress concentrations that promote vacancy generation, thereby accelerating the transition from transgranular to intergranular fracture. We further show that hydrogen dramatically enhances strain- induced vacancy stockpiling, leading to nanovoid nucleation and intergranular failure once a critical vacancy threshold is reached. External loading states exert dual influences by reshaping the hydrogen segregation spectrum, creating super-trapping sites and short-circuit diffusion channels within GB cores. Together, these findings establish a unified mechanistic picture of hydrogen-controlled vacancy dynamics and GB segregation, offering new insights into the fracture mode transition in nickel. This work advances fundamental understanding and predictive capability of hydrogen embrittlement in structural materials.

Keywords: Hydrogen embrittlement; nanovoid; intergranular fracture; segregation energy; grain boundary

Acknowledgement

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ACOUSTIC, MAGNETIC AND STRUCTURAL CHARACTERISTICS OF CYCLIC DEGRADATION OF TRADITIONAL AND ADDITIVELY MANUFACTURING STEELS

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Abstract

The mechanical properties, acoustic emission (AE) characteristics, digital image correlation (DIC) parameters, damage parameters, and coercive force of 12Cr18Ni10T steel with various grain sizes and additively manufactured 316L steel, subjected to preliminary cyclic loading followed by tension to failure were evaluated. The acoustic emission characteristics during tension included AE signal activity ($\dot{N}$), the total number of signals (ΣN), the RA-value (the ratio of the signal rise time to its amplitude), and the b-value, which reflects the proportion of high-amplitude signals.

An algorithm for processing specimen surface micrographs was developed and applied to analyze the damage of the steels during cyclic and subsequent static loading. This algorithm allows for the determination of key damage criteria: the area of the damaged surface (S^*), the average length (LAV) and density (n) of microcracks, as well as the concentration criterion k , estimated by the ratio $k = 1 / (LCP\sqrt{n})$.

It was established that the nucleation of fatigue microcracks in the additively manufactured 316L alloy occurs at melt pool boundaries, and the kinetics of damage accumulation is described by the S^* criterion, which correlates with the relative number of preliminary loading cycles (N/N_f). The characteristic size of microcracks in this steel is larger than the size of microcracks in traditional produced 12Cr18Ni10T steel. Tests of 12Cr18Ni10T steel with a coarse grain size ($d = 280 \mu\text{m}$ after quenching at 1200°C) demonstrated earlier and more intensive microcrack formation compared to the fine-grained material ($d = 21 \mu\text{m}$). The formation of deformation martensite, which contributes significantly to the damage accumulation process, was detected using X-ray diffraction (XRD) analysis and electron backscatter diffraction (EBSD).

Quantitative relationships were established between the damage parameters, physical properties (magnetic and acoustic), and the characteristics of the plastic zones and principal strain assessed by DIC analysis. The results of the acoustic emission parameter study showed that cyclic degradation leads to a decrease in the total number of events, AE activity and b-value, and an increase in the RA-value. An exponential dependence of S^* on the maximum principal strain was demonstrated. A correlation between coercive force, acoustic emission, and the degree of damage was noted. Analysis of the kinetics of the studied parameters allowed for the identification of stages in the fracture process, which correlate with the sample deformation stages and cyclic degradation criteria.

Keywords: Damage, microcracks, additive manufacturing, non-destructive testing, digital image correlation

Acknowledgement

The study was carried out with funds from the Russian Science Foundation (project No. 23-19-00784).

ELECTRICAL CONDUCTIVITY OF FRICTION STIR WELDED ALUMINIUM JOINT

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Abstract

Friction stir welding has proven to be a good process for joining materials because the welded joint has good mechanical properties. The aim of the study is to examine the electrical conductivity of the welded joint, because it tells about the quality of the welded joint, i.e. on the homogeneity of the structure. By experimentally welding 2 aluminum plates with a thickness of 3mm, AA5754-H111, a lap joint was obtained. This paper provides a description of the technological parameters for experimental welding, macrostructural images of the joint and the electrical conductivity of the joint. The joint was successfully welded with the selected technological parameters. The macrostructural images clearly show the nugget zone, as well as the joint without defects of two types: bonding line (kissing bond) and the unwelded root. The measurements that were made show that the electrical conductivity is almost constant over the entire section of the joint, from the base metal zone to the weld zone, which indicates that the mixing in that part is excellent and that a homogeneous material is obtained in the weld zone.



Figure 1. Cutting samples for measuring electrical conductivity

Keywords: Electrical conductivity; Macrostructure; Friction stir welding; Non-destructive testing

Acknowledgement

We thank Dr Uroš Stamenković, associate professor, and Tamara Perišić, laboratory technician (University of Belgrade - Technical Faculty in Bor) for the coarse and fine preparation of the samples, and for microhardness and electrical conductivity measurements.

EVALUATION OF TENSILE DAMAGE EVOLUTION BEHAVIOUR OF ADDITIVELY MANUFACTURED ALUMINIUM ALLOY USING SR-CT, DVC AND MICRO-FE

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Abstract

Additively manufactured (AM) aluminum alloys tend to exhibit large deformation of internal pores and induce strain concentration under tensile loading, leading to changes in local porosity, which in turn affects the material's mechanical behaviour. To explore this process in depth, this study systematically investigates the tensile damage evolution behaviour of AM aluminum alloys by combining advanced characterization techniques with numerical simulation methods. First, axial tensile loading was applied, and in-situ synchrotron radiation computed tomography (SR-CT) was used to obtain real-time images of the internal microstructure of the specimens. A 3D image reconstruction algorithm was employed to analyze the spatial distribution characteristics of pores and their evolutionary relationship with cracks. The SR-CT experimental results indicated that the damage evolution of pores could be divided into three stages: expansion of initial pores, initiation of micro-pores, and connection of pores to form macroscopic cracks. Then, digital volume correlation (DVC) technology was used to quantitatively characterize the internal strain field distribution of the specimens, and the region with the maximum internal stress concentration was identified, which was consistent with the final fracture location. To further reveal the failure mechanism, the 2D defect distribution at the failed fracture was combined with the 3D evolution law of internal defects, and the key defects inducing failure were identified. Based on these defects, a full-scale micro-finite element (FE) model of the AM aluminum alloy specimen was established. This model enables a clearer analysis of the stress concentration caused by pores and micro-defects and its evolution during the tensile process, reveals the action mechanism of different defects in the tensile process, and further predict their influence on the final failure behaviour of the specimens.

Keywords: Aluminium alloy; Pores; SR-CT; DVC; Finite element analysis

Acknowledgement

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A MODELLING APPROACH TO ESTIMATE THE DIFFUSION AND TRAPPING CONSTITUTIVE PARAMETERS FOR 2.25Cr1Mo

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Abstract

Carbon emission abatement policy is pushing toward the usage of hydrogen as an energy storage and carrier medium, but its spread requires dedicated infrastructures that must satisfy high safety standards. To this purpose, high-strength low-alloyed steels are commonly used as structural steels in the hydrogen value chain. However, this class of materials exhibits hydrogen susceptibility. The strength and toughness loss is related to the hydrogen concentration dissolved into the material. Since hydrogen concentration may vary over time due to hydrogen diffusion and trapping, it is essential to determine the constitutive laws governing hydrogen diffusion and trapping for the design and inspection of structural components exposed to hydrogen.

The aim of this research is the estimation of diffusion and trapping constitutive parameters of a 2.25Cr1Mo alloy, being this one of the most utilized structural materials in the power sector. Electrochemical permeation tests using a Devanathan-Stachurski cell and a multi-step, multi-temperature approach, together with a Temperature Desorption Spectroscopy (TDS) campaign on pre-charged samples with different thicknesses, were performed. Experimental results show how the interpretation of permeation data based on the methods published in the scientific literature is insufficient to identify the constitutive laws and the constitutive parameters governing the hydrogen diffusion and trapping for the examined material. A data-driven modelling approach based on successive generalizations is presented and discussed, aiming towards identifying the simplest model capable of explaining all the experimental results with sufficient accuracy.

Keywords: Hydrogen embrittlement; high-temperature low-alloyed steels; electrochemical permeation testing; thermal desorption analysis; material modelling.

INVESTIGATION ON THE SYNERGISTIC OPTIMIZATION STRATEGY OF POROSITY AND NICKEL CONTENT ON REDOX THERMAL STRESSES IN Ni-YSZ ANODES

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Abstract

The severe thermal stresses induced by reduction-oxidation (RedOx) cycles pose critical challenges for the thermomechanical stability and long-term reliability of solid oxide fuel cell (SOFC) anodes. This study, for the first time, introduces a multiphysics finite element framework that systematically evaluates the synergistic impacts of anode sintering porosity, nickel content, and resultant oxidation expansion strain on thermal stress distribution and failure probability. In this study, Ni content is expressed in weight percent (wt%), while porosity is expressed in volume percent (vol%). A nonlinear synergistic effect between initial porosity and nickel content was identified, demonstrating that high porosity (40 vol.%) substantially mitigates electrolyte tensile stress by up to 59.8% by accommodating expansion strain during reoxidation. Moreover, reducing nickel content to 40 wt% (~25.8 vol.% Ni after reduction) significantly suppresses electrolyte stress increase during reduction, lowering it by over 60%. A predictive regression model was established, accurately quantifying the interplay between these variables ($R^2 = 0.98$). The proposed “40 vol% porosity and 40 wt% Ni content” strategy decreases electrolyte failure probability by two orders of magnitude, aiming to mitigate RedOx-induced thermal stress and failure risks in planar Ni–YSZ anodes within a realistic parameter space.

Keywords: Solid oxide fuel cells; Redox-driven stress evolution; Thermomechanical stress; Porosity; Nickel content

VERIFICATION OF RESULTS OF PILE INTEGRITY TEST

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Abstract

The Sonic Integrity Test (SIT) is a sonic echo method based on the theory of one-dimensional stress wave propagation. By striking the pile head with a hand hammer, a compression wave is generated that propagates along the pile shaft and reflects from the pile base. An accelerometer (sensor) attached to the pile head records the accelerations caused by the wave reflections within the pile. Any change along the pile shaft, such as enlargement or reduction of the cross-section or variation in material quality, produces wave reflections that are captured by the sensor as changes in acceleration. By integrating the acceleration, a velocity record over time is obtained and displayed digitally. This represents the final product of the test, providing data on the quality of the constructed pile. Pile integrity testing is the first step in quality control of constructed piles followed by load-bearing capacity control by static or dynamic method. Interpretation of the test results is subjective and may contain a certain degree of uncertainty. In this paper, two practical examples are presented in which deviations from the expected shape of the reflectogram were identified by integrity testing. The irregularities were located in the shallow zones of the pile shaft, which enabled visual verification of the results after excavation around the pile head. In the first case, instability of the embankment during pile construction caused soil collapse into the borehole, which resulted in a negative reflection immediately after the initial impulse on the signal. The pile concrete within the top 5 m was of poor quality and prone to disintegration, and the remediation measure was to replace the pile with a new one. In the second case, the anomaly observed on the signal was the consequence of heavy inflow of groundwater, which washed out the concrete in the upper 3 m of the pile. After reaching sound concrete during excavation, formwork was placed and the pile was concreted up to the design level. The integrity test was repeated, and the return signal showed a positive result, with a minor negative reflection at the interface between the new and old concrete. These examples confirm the reliability and efficiency of this simple and rapid method in assessing the integrity of constructed piles. The experience of the engineer conducting the test is of crucial importance for the proper interpretation of the reflectogram. Pile integrity testing provides a fast and economical means of detecting potential irregularities at an early stage of the project, which may otherwise compromise the safety and functionality of the structure in service. In such cases, remediation during the foundation construction phase is technically simpler and more cost-effective, which emphasizes the significance and justification of implementing pile integrity testing.

Keywords: pile; integrity; reflection; velocity

VISUALIZATION OF TENSILE DAMAGE EVOLUTION OF 3D BRAIDED CARBON FIBER COMPOSITES USING MECHANOCROMIC LUMINESCENT SENSING FILM

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Abstract

Three-dimensional braided carbon fiber reinforced epoxy composites are used as structural materials for aerospace and automotive industries. Rapid detection of structural damage and structural integrity assessment are critically important for structure safety. In this study, a novel detection technique based on mechanochromic luminescent sensing film is developed to detect tensile damage of 3D braided carbon fiber reinforced epoxy composites. The local deformation in the composites is converted into the visible mechanoresponsive fluorescence response under uniaxial tension. According to the fluorescence distribution, the evolution of structural damage can be observed directly. Moreover, after image processing and image feature value extraction, the relationship between structural damage and image feature value can be established. The proposed method may provide a new idea for developing a simple and visual detection method for structural damage in 3D braided carbon fiber composites.

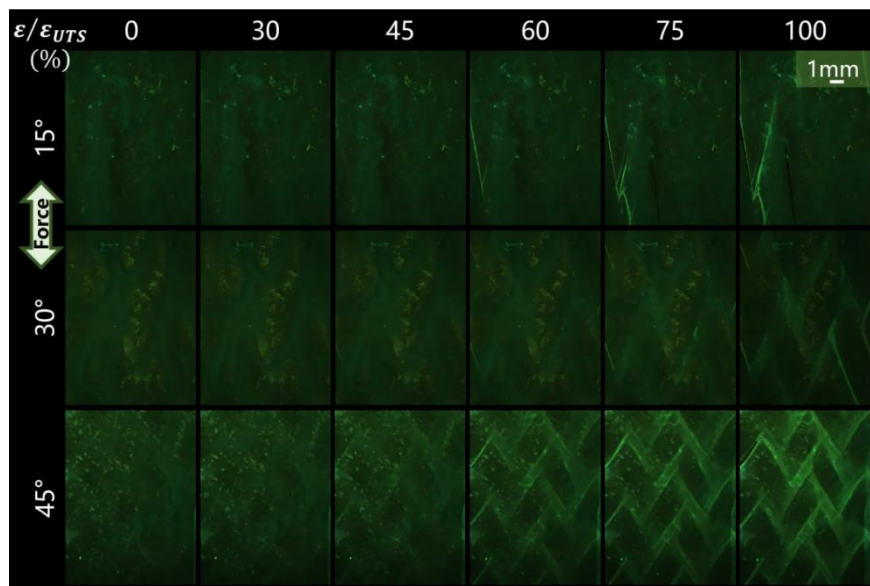


Figure 1. mechanoresponsive fluorescence response of 3D braided carbon fiber composites under tensile deformation.

Keywords: Carbon fiber composites; Mechanochromic luminescent material; Tension; Damage evolution; Visualization

Acknowledgement

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APPLICATION OF MODERN TEST METHODS AND ENGINEERING PRACTICE ON PRESSURE VESSELS

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Abstract

In welding, a highly multidisciplinary field, quality assurance is crucial. Even minor deviations from the stringent requirements set by welding standards can lead to defects in welded joints. This is especially true for pressure equipment fabricated with materials for high-temperature service, where small variations in key parameters almost inevitably cause defects. When defects are detected and the installation of new components is not an option, a numerical simulation can be an effective modern method to assess the integrity of the weld. By interpreting the results of these simulations and combining them with sound engineering practice, the reliability and functionality of the component can be proven, minimizing the need for costly rework or replacement. For example, indications were found in the superheater tubes of Steam Boiler 1, fabricated for the "Šoštanj" Thermal Power Plant in Slovenia. These were discovered using destructive testing methods, as conventional nondestructive testing methods, which were mandated for final inspection, failed to detect them. A detailed analysis revealed the root cause: an excessively high quality class for the welded joints was specified in the design, exceeding what was necessary.

While the designer correctly prioritized the structural integrity and load-bearing capacity of this pressure equipment, the attempt to achieve an unnecessarily high-quality class of welds resulted in inadequate preparation. This, in turn, made the occurrence of defects in the welded joints inevitable.

To prove the load-bearing capacity of the welded joints, a numerical simulation was performed. This simulation demonstrated the welds' resistance to static load for several potential loading scenarios, even with critical indications present at the weld root. The simulation also provided the values for the maximum possible loads before the onset of plasticity.

Keywords: Pressure equipment; creep-resistant steels; welded joint defects; engineering practice; numerical simulations

Acknowledgement

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APPLICATION OF ACCURATE ELASTIC WAVE ARRIVAL TIMES FOR ACOUSTIC EMISSION SOURCE LOCALIZATION IN GEOMATERIALS

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Abstract

Acoustic Emission (AE) source localization has the potential to contribute to studies on progressive failures in geomaterials. However, the localization has not been widely applied to geomaterials except rocks, and its accuracy should be improved. In the measurement of AE signals generated in geomaterials composed of granular materials, the measured signals possibly include low S/N signals since the transmission losses occurring between particles decrease the amplitudes. Although arrival times of AE signals at installed sensors are required to conduct the localization, detecting arrival times in low S/N signals is challenging. Thus, if high S/N signals are only applied to the localization, since accurate arrival times can be detected from high S/N signals, it is expected that the accuracy of the localization is improved in geomaterials. In this study, the measurement parameters were set to only measure high S/N signals in pile penetration test conducted on the soil specimen. Further, the measured signals are applied to AE source localization. In the results of the localizations shown in Figure 1, the localized sources visualized the failures and the localized sources are consistent with the trends observed in the pile penetration process reported in the previous studies. Thus, the results implied that accurate arrival times contribute to the accurate AE source localization in the soil specimen. Moreover, Self-Organizing Map (SOM) which is an unsupervised learning method was applied to the measured signals, and the result implied that measured signals included a large number of high S/N signals. Therefore, it is expected that SOM will validate the applicability of measured signals for AE source localization.

Keywords: AE source localization; Arrival time; Geomaterial; SOM

Acknowledgement

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MEASUREMENT OF INTERFACIAL ADHESION IN A THERMAL BARRIER COATING SYSTEM ON NI-BASED SUPERALLOYS: EFFECT OF TEST CONFIGURATION

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Abstract

Measuring parameters of the resistance to interfacial deboning (adhesion) is one of the key factors to predict the durability of thermal barrier coatings system (TBCs) during operation under severe conditions. This work aims to develop a new experimental technique to quantify the interfacial adhesion in TBC system on Ni-based superalloys. Based on the analysis of existing methods and approaches to measurer the adhesion parameters for multi-layered structurally heterogeneous TBC systems, a new design of samples and test fixtures are proposed [1].

The obtained test results are discussed in a strong correlation with microstructural analysis, which is employed to study TBC thickness, its uniformity and geometry of the interfaces in pristine samples as well as to control the occurrence and spread of spallation during testing.

It has been previously shown that the residual stresses developed during thermal cycling are of primary importance, as their magnitude and distribution govern the durability of TBC systems. Numerical study is carried out using a finite element model based on representation of the contact between TBC components as a cohesive interaction.

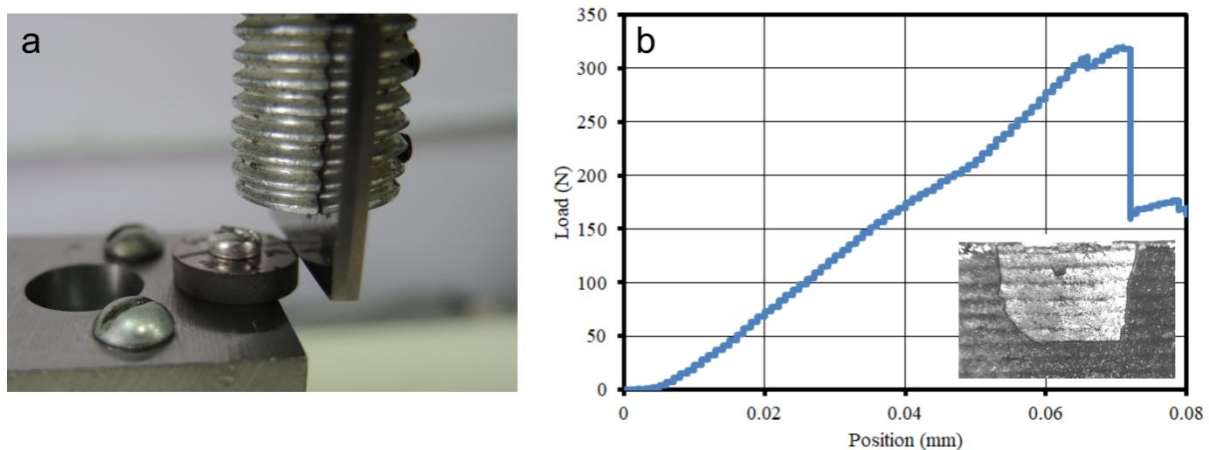


Figure 1. Loading fixture for Tinius Olsen H25KT testing machine (a); experimental curve and spallation area of TBC on Ni-based superalloy (b).

Keywords: Ni-based superalloy; TBCs; interfacial adhesion; microstructural analysis; FEM

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COMBINED APPROACH FOR INTEGRITY ASSESSMENT OF WELDED JOINTS WITH MULTIPLE DEFECTS

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Abstract

Presence of various types of defects is an unavoidable issue when it comes to welded joints. Typical approach to dealing with this problem includes the effects of individual defects, without considering the combined influence of several different defect types on the integrity of a welded joint. Research which will be presented here includes the initial steps and the development of a method for analysing the effects of multiple types of welded joint defects, using a number of different approaches - with the main focus on experiments and numerical simulations based on the finite element method. This research, inspired by real problems encountered in engineering practice, initially focused on the geometry of welded joints with defects, as an important factor in terms of stress concentration, which could decrease the load-bearing capacity of a weld by a significant margin. As the methodology continued to develop, experimental tests were included, in order to provide input data for the numerical models, and to verify their accuracy. The experimental part of this research was further improved by combining it with stereometric monitoring methods - mainly Digital Image Correlation (DIC). In this way, a more detailed insight into the behaviour of welded joints with defects was obtained, providing an extensive and reliable base of information, which could be used by and compared to the numerical simulations.

In the more recent experimental and numerical analyses, the welded joint itself for considered in more detail, by observing each of its regions - the parent material (PM), the weld metal (WM) and the heat affected zone (HAZ) - in terms of mechanical properties. The goal was to include different values of yield stress, tensile strength and deformation for each individual zone, which would correspond to the experimentally determined values. For the HAZ, it was not possible to experimentally obtain these values, hence an iterative method was developed to determine them using the FEM models, by comparing the results with DIC images.

Metallurgical aspects were also an important factor which was included in these analyses, as knowledge about what kind of microstructures occurred in each region during welding was crucial in determining the expected mechanical properties of the HAZ. Due to specific conditions during welding (in order to obtain relevant defects), it was assumed that the microstructures would deviate from those obtained under regular conditions.

Taking all of the above into consideration resulted in a quick, effective and reliable method of determining the influence of multiple defects on the structural integrity of welded joints. Next step, which are currently underway, include the application of this methodology to a different combination of materials - namely a welded joint between a ferritic steel and an austenitic stainless steel.

Keywords: welding defects; structural integrity; digital image correlation; finite element method; welded joint region

NON-DESTRUCTIVE TESTING TECHNIQUES FOR ASSESSING MATERIAL DEGRADATION IN RAILWAY DRAW HOOKS

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Abstract

Railway draw gear components, such as draw hooks compliant with EN 15566 standard, play a crucial role in ensuring operational stability and safety in rolling stock. While component failures are infrequent, they can result in significant disruptions to vehicle performance, often manifesting as unexpected fractures under service conditions. This investigation employs non-destructive testing (NDT) methods to evaluate material degradation, with a focus on fatigue-driven mechanisms in draw hooks. Utilizing high-precision device like the Leica M205 A stereomicroscope equipped with apochromatic zoom capabilities and digital stage control, the study examines fracture surfaces at sub-millimeter resolutions to identify initial crack sites and propagation patterns. Stereomicroscopic imaging reveals filamentary structures indicative of progressive fatigue, where cracks initiate at stress concentration points and advance through trans granular paths under cyclic loading. Potential causes of such failures include repeated mechanical stresses exceeding design limits, inadequate maintenance leading to undetected defects and built-in material anomalies derived from manufacturing processes.

These findings highlight the importance of early intervention to prevent catastrophic failures in railway operations. The analysis extends beyond imaging by incorporating stress distribution data from operational logs, with additional validation performed at the Military Technical Institute (VTI) using advanced data processing techniques. Preliminary results suggest that optimizing maintenance intervals based on NDT outcomes could significantly extend component lifespan. Future efforts will focus on validating these observations through real-time monitoring systems, integrating sensor-based technologies to track fatigue progression dynamically and proposing updated design standards to enhance durability under varying operational conditions. Additionally, dynamic load analysis using appropriate software, such as MSC Adams, will provide a clearer image of the behavior of each draw gear part and the dynamic load impact on them.

Keywords: NDT; Fatigue damage; Draw hooks; Railway components; Structural integrity

Acknowledgement

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INTRODUCTION TO NEUTRON IMAGING AT IMAT: RADIOGRAPHY, TOMOGRAPHY AND STRAIN MAPPING

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Abstract

Neutron imaging at IMAT, part of the ISIS neutron spallation source at Rutherford Appleton Laboratory, UK, is a cutting-edge tool for materials science, offering capabilities in radiography, tomography, and strain mapping. IMAT employs energy-selective and energy-dispersive imaging to provide comprehensive analysis of materials. Radiography creates detailed 2D images by measuring neutron attenuation through a sample, while tomography reconstructs 3D images from multiple radiographic projections. Strain mapping via time-of-flight neutron diffraction measures internal stresses and strains, critical for understanding material performance.

Unlike X-ray, neutron imaging is particularly effective for visualizing light elements such as hydrogen, lithium, and boron, and for inspecting complex, dense structures where X-rays might fail. Neutrons are highly penetrating and can differentiate between isotopes, providing unique insights into the composition and internal features of materials. This makes neutron imaging an invaluable tool for applications ranging from industrial non-destructive testing to the analysis of cultural heritage artifacts. IMAT has been utilized for various applications, such as analyzing ancient Chinese arrowheads, studying the metallurgy of historical artifacts, observing hydrogen adsorption in catalysts, and investigating battery performance. These examples highlight the versatility and power of neutron imaging in both historical research and modern materials science.

This presentation aims to introduce the capabilities of IMAT in neutron imaging, focusing on its applications in radiography, tomography, and strain mapping (as shown in Figure 1). We will explore how IMAT's advanced techniques contribute to materials science and engineering, providing insights into both historical artifacts and contemporary technological challenges.

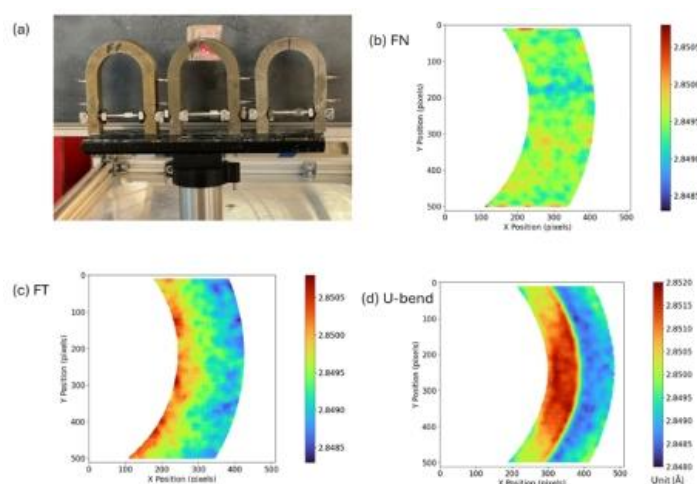


Figure 1. (a) Experimental setup for the Bragg-edge imaging experiment. The three U-shape samples were mounted in front of the MCP detector at IMAT neutron imaging beamline. Bragg-edge maps of lattice parameter for (b) FN, (c) FT, and (d) U-bend specimens. FN is uniform in lattice parameter. FT displays a smooth lattice-parameter gradient. U-bend exhibits a sharp tensile-compressive gradient.

Keywords: Neutron imaging, Radiography, Tomography, Strain mapping, Bragg edge

DETERMINATION OF MECHANICAL PROPERTIES AND RESIDUAL STRESS OF LOW ACTIVATION MARTENSITIC STEEL WELDED JOINTS BY INSTRUMENTED INDENTATION TECHNIQUE

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Abstract

Low Activation Martensitic steel has been recognized as a promising structural material for nuclear fusion reactor applications due to its superior irradiation resistance and mechanical properties. However, the presence of weld joints in key components inevitably introduces heterogeneous microstructures and residual stresses, which critically affect their long-term service reliability. Conventional measurement methods are destructive in nature, making them unsuitable for in-service evaluation. In this study, we employed Instrumented Indentation Technique (IIT) as a localized, minimally destructive approach to evaluate both the mechanical properties and residual stress states of Low Activation Martensitic steel welded joints. By analyzing load-displacement curves obtained at different weld zones, including base metal, heat-affected zone, and weld metal, key parameters such as yield strength and strain hardening exponent were quantitatively derived. Moreover, the spherical indentation was tentatively applied to assess the residual stress distribution near the weld interface. The experimental results reveal significant spatial variations of mechanical properties across different zones, which can be attributed to microstructural inhomogeneity induced by welding. In particular, compressive and tensile residual stresses were identified near the weld region, demonstrating the capability of IIT in capturing surface residual stress heterogeneity in weld joints. The findings of this study contribute to the advancement of Low Activation Martensitic steel material development, welding processes optimization, and structural integrity assessment. Currently, uniaxial tensile testing, and XRD experiments are being gradually conducted to comprehensively validate the accuracy of IIT on Low Activation Martensitic steel welded joints. This research may be extended to other fusion-relevant structural materials, contributing to the safe design and lifetime assessment of next-generation nuclear energy systems.

Keywords: China low activation martensitic steel; Instrumented indentation technique; Mechanical properties; Residual stress; Welded joints

Acknowledgement

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3D DAMAGE EVOLUTION IN SiCf/SiC COMPOSITES AT 1800°C: A QUANTITATIVE STUDY OF PORES AND STRAIN FIELDS BY IN-SITU μ CT AND DVC

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Abstract

This study utilized in-situ X-ray micro-computed tomography (μ CT) combined with digital volume correlation (DVC) to investigate the tensile damage and failure mechanisms of third-generation SiCf/SiC composites under both room temperature and 1800 °C conditions. The analysis encompassed defect characterization, damage evolution, fracture modes, and failure behaviors. Results indicate that elevated temperature induces substantial alterations in the material's macroscopic mechanical properties and failure behavior: tensile strength decreased markedly from 347 MPa at room temperature to 177 MPa at 1800 °C. The fracture mechanism transitions from distributed damage—characterized by multiple cracking, delamination, and fiber pull-out—at room temperature, to localized failure at high temperature, dominated by a single primary crack and accompanied by pronounced necking. Three-dimensional pore quantification revealed the underlying micromechanisms: high temperature significantly accelerates the early initiation and coalescence of micro-pores and intra-bundle pores (with growth exceeding 300%), thereby promoting strain localization. In contrast, damage at room temperature is primarily governed by the extension of inter-laminar pores. Full-field strain maps derived from DVC measurements further confirm that the region of maximum axial strain (ϵ_{zz} peak) within the necking zone aligns precisely with the final fracture path. Fractographic analysis via scanning electron microscopy (SEM) corroborates that this mechanistic transition arises from the synergistic effects of enhanced fiber-matrix interfacial bonding and matrix softening at elevated temperatures. This work elucidates that pore evolution and strain localization are critical drivers of high-temperature performance degradation, offering essential experimental insights and guiding principles for the design of high-reliability SiCf/SiC composites intended for extreme environment applications..

Keywords: SiCf/SiC composites, X-ray micro-CT, High-temperature, Digital image correlation(DVC)

IDENTIFYING CRITICAL DAMAGE USING THE ACOUSTIC EVENTS OF AMPLITUDE EXCEEDING THEIR MEAN VALUE

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Abstract

The aim of this study is to assess the efficiency of a novel approach for the prediction of upcoming fracture. This approach is based on the analysis of the time series of the cumulative number of acoustic events the amplitude of which is greater than (or equal to) the average value of the amplitudes of all the events recorded during the loading and fracture procedure of a given specimen (or structure). Using then the “sliding window” technique it is possible to determine the average slope, $\bar{m}_A$, of the evolution of the above time series, either against the Conventional Time (in seconds) or against the Natural Time [1] (the latter offers a uniform distribution of the acoustic events throughout the duration of the experiment).

For the needs of the present study, experimental data from an already published protocol [2] (with notched, beam-shaped specimens, made of either plain or fiber-reinforced concrete, under 3-point bending) were used. A typical example of the results of this approach is exhibited in Fig.1, in which the evolution of the parameter $\bar{m}_A$ is plotted in juxtaposition to the respective one of the (normalized) applied load. In Fig.1a the plots are realized against the Natural Time, χ , while in Fig.1b against the Conventional Time, in terms of the time-to-failure parameter, $t_f - t$, (in logarithmic scale), where t_f is the fracture instant.

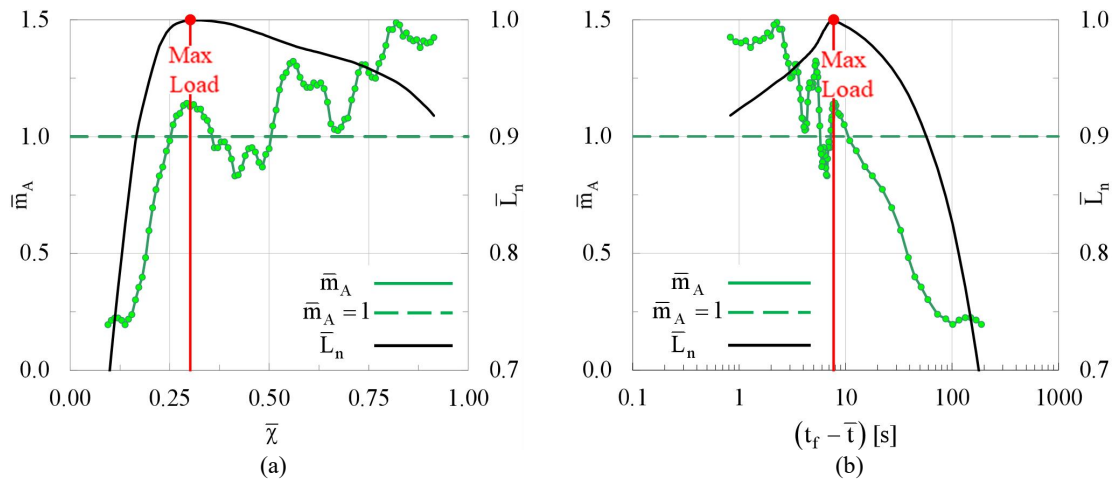


Figure 1. The evolution of the average slope of the cumulative number of events with amplitude exceeding the respective average, in juxtaposition to that of the normalized average load ($\bar{L}_N$), for a plain concrete specimen.

It is seen that while the applied load increases, the parameter $\bar{m}_A$ exhibits a monotonously increasing trend towards a value equal to unity (attained a few seconds before the load attains its peak value), while at the instant of load maximization it exhibits a local extremum and starts decreasing. The specific response, which is systematic for all the specimens of the protocol, suggests that the evolution of $\bar{m}_A$ could be considered as providing a pre-failure index, i.e., the attainment for the first time the value of unity.



Keywords: Criticality; Damage; Acoustic Emissions; Natural Time; Concrete

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MECHANICAL PROPERTIES OF $\text{Hf}_x\text{Ta}_{1-x}\text{C}$ SOLID SOLUTION ON *AB INITIO* LEVEL

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Abstract

Tantalum and hafnium carbides are categorized as ultrahigh-temperature ceramic materials because of their elevated melting temperatures that rank among the greatest for inorganic materials. Additionally, trial-based and conceptual studies have indicated the outstanding properties of HfC and TaC related to elasticity and mechanics, rendering them appropriate for use as structural materials in various uses, for instance, as heat insulation resources for the upcoming era of hypersonic automobiles. Recently, mixed hafnium-tantalum carbides have been of great scientific and industrial attention due to their structural characteristics and thermal, elastic, and mechanical properties. [1,2] In this study, we have investigated the mechanical properties of the mixed $\text{Hf}_x\text{Ta}_{1-x}\text{C}$ ($x = 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875$, and 1) solid solution. Mechanical and elastic properties, including bulk, shear, Young's moduli, elastic constants, and the Vickers hardness, were computed using a combination of atomistic DFT methods and the recently developed KOVIN algorithm. We believe that the present study will help in understanding the structure-property relationship in mixed $\text{Hf}_x\text{Ta}_{1-x}\text{C}$ solid solutions.

Keywords: HfC; ab initio; TaC; mixed HfTaC; Mechanical properties

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CT AND IMAGE POST-PROCESSING FOR FIBER COMPOSITES: DEFECT ANALYSIS, DEEP LEARNING, DIGITAL VOLUME CORRELATION, AND FE SIMULATION – A REVIEW

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Abstract

X-ray computed tomography (CT) has emerged as a transformative tool for multiscale damage characterization in fiber composites (FCs), with industrial CT and synchrotron radiation CT (SR-CT) offering complementary high-resolution capabilities. This review presents a critical synthesis of cutting-edge advancements in CT-based analysis. A discussion is conducted for CT modality selection, optimizing the trade-offs between SR-CT's nanometer resolution and industrial CT's cost efficiency. The Deep learning architectures overcome traditional segmentation limitations in low-contrast, multiphase FCs, enabling precise defect quantification. A hybrid digital volume correlation (DVC) method is proposed integrating subset-based local and finite element (FE) global algorithm, considering different increments. The Peridynamics-enhanced FE simulation method resolves crack propagation challenges through CT-image-driven modeling. We demonstrate how these synergies enable unprecedented 3D defect visualization under in-situ mechanical loading (tension/ compression/ fatigue), while AI-powered segmentation and DVC-derived strain fields bridge experimental data with microstructure-sensitive simulations. The review concludes with an outlook on emerging opportunities in automated CT post-processing pipelines and multiscale peridynamics-FE frameworks, addressing current bottlenecks in composite damage prediction for aerospace and energy applications.

Keywords: Micro-CT; fiber-reinforced composites; defect analysis; deep learning; digital correlation

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- K. Telebak, I. Trajković, M. Milošević - *Experimental study of head and neck biomechanics under impact conditions with a protective helmet*
- S. Homon, A. Pavluk, S. Gomon, M. Skrypnyk, P. Gomon, R. V. Pasichnyk, O. Pasichnyk, V. Kovalchuk - *The influence of low-cycle loads on the position of the neutral line in obliquely compressed reinforced concrete elements*

DAMAGE-BASED FRAMEWORK FOR FATIGUE LIFE PREDICTION OF FILAMENT-WOUND COMPOSITES UNDER MULTIAXIAL CYCLIC LOADING

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Abstract

With the growing use of carbon fiber-reinforced polymers (CFRPs) in engineering structures such as pressure vessels, wind turbine blades, and aircraft fuselages, the need for accurate modeling of their mechanical response under fatigue loading has steadily increased. Fatigue models are typically categorized as phenomenological or damage-based, with the latter often incorporating multiscale approaches. In fiber-reinforced polymers, multiple failure mechanisms may act across different length scales and may occur simultaneously. Therefore, identifying the dominant damage mode and incorporating it into fatigue modeling is essential.

The objective of this research is to apply a modified Fatemi-Socie parameter to model damage in filament-wound composites subjected to multiaxial cyclic loading. A numerical model with shear-nonlinear behavior was employed for stress analysis, from which the critical value of the damage parameter was determined and subsequently used for fatigue life estimation. The study examines the influence of parameters such as mean stress, out-of-phase loading, and biaxiality ratio. The obtained results demonstrate good agreement between the proposed modeling approach and both the author's experimental data and literature results.

Keywords: Multiaxial fatigue; Continuous fiber composites; Nonproportional loading; Fatigue life prediction

Acknowledgement

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MECHANICAL RESPONSE PREDICTION OF HYBRID COMPOSITE REBARS FOR CONCRETE APPLICATIONS VIA MICROMECHANICAL MODELING

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Abstract

Composites are an advanced materials that are progressively replacing conventional metals across a range of engineering applications. Fiber Reinforced Polymers (FRPs), in particular, exhibit distinct failure mechanisms compared to isotropic materials, including fibre breakage, matrix cracking, and delamination. The hybridization of reinforcement within composite structures enables the synergistic utilization of multiple fibre types, resulting in enhanced mechanical performance such as tensile strength that cannot be accurately predicted by the traditional Rule of Mixtures.

One notable application of such materials is in the production of composite reinforcement bars (rebars), where FRPs serve as substitutes for conventional steel reinforcement. Accurate prediction of the ultimate tensile strength of unidirectional FRP systems, as well as comprehensive assessment of mechanical behaviour in various hybrid configurations, is essential for the design and optimization of such structural components.

To assess the mechanical performance of composite rebars, a series of analytical models were employed. According to the assumption proposed by Vanegas-Jaramillo, failure under axial tensile loading occurs when the density of fibre fractures reaches a critical threshold. Based on fibre property distributions modelled via the Weibull statistical approach, along with experimentally determined matrix properties and interfacial bond strengths, the Neumester fragmentation model—also referred to as the Critical Number of Breaks (CNB) model—was applied to predict damage behaviour.

Manufactured composite profiles incorporating varying proportions of glass and carbon fibres were analysed to evaluate their mechanical response. A comparative investigation of the stress–strain behaviour was conducted for both intermingled and interlayered hybrid reinforcement configurations. Based on the analytical findings, an optimal fibre composition was identified. Subsequently, hybrid composite rebars were fabricated using the pultrusion process.

Model predictions were validated through experimental testing, using Digital Image Correlation (DIC) to capture full-field strain distributions. Additionally, the damage mechanisms inferred from the analytical models were compared with in-situ failure events recorded via an Acoustic Emission (AE) monitoring system.

Keywords: composite structure; rebars; micromechanics; hybrid

Acknowledgement

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MOLECULAR DYNAMICS INVESTIGATION OF PLASTIC DEFORMATION IN POLYCRYSTALLINE Ti-13Mn WT.% ALLOY

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Abstract

Titanium alloys are widely used in the aerospace, biomedical, and energy engineering domains due to their high specific strength, corrosion resistance, and biocompatibility. Among these, β -type titanium alloys are particularly desirable for high-performance material design, leveraging microstructural control. In this work, we investigate the atomic-scale deformation behavior of the Ti-13Mn wt.% alloy to gain fundamental insights into its mechanical performance.

Molecular dynamics (MD) simulations were performed at room temperature on polycrystalline structures to assess the role of grain boundaries in plasticity. Tensile loading was applied at strain rates ranging from 10^{-9} to 10^{-7} s⁻¹ in order to evaluate strain-rate sensitivity. The analysis focused on strain response, Schmid factor, slip system activation, and dislocation behavior.

We track dislocation nucleation during mechanical testing by reporting dislocation density as a function of strain, along with the visualization of the dislocation network at different strain values. The results show that strain localization, dislocation nucleation, and grain boundary interactions are the primary mechanisms governing plastic deformation in Ti-13Mn wt.%. Strain-rate effects were linked to the equilibrium between dislocation motion and grain boundary accommodation. This study provides new insights into the relationship between the mechanical performance of Ti-13Mn wt.% alloy and its microstructural properties, supporting the design of improved β -type titanium alloys.

Keywords: Molecular Dynamics; Plastic Deformation; Titanium Alloys; Manganese; Microstructure

Acknowledgement

Research was funded through the European Union Horizon 2020 research and innovation program under Grant Agreement No. 857470 and from the European Regional Development Fund under the program of the Foundation for Polish Science International Research Agenda PLUS, Grant No. MAB PLUS/2018/8, and the initiative of the Ministry of Science and Higher Education “Support for the activities of Centers of Excellence established in Poland under the Horizon 2020 program” under Agreement No. MEiN/2023/DIR/3795. The Ministry of Science, Technological Development, and Innovation of the Republic of Serbia, grant No. 451-03-136/2025-03/200023. We gratefully acknowledge Polish high-performance computing infrastructure PLGrid (HPC Center: ACK Cyfronet AGH) for providing computer facilities and support within computational Grant No. PLG/2024/017084.

AN INTEGRATED HRDIC FRAMEWORK FOR SLIP SYSTEM IDENTIFICATION AND CRSS DETERMINATION IN HCP POLYCRYSTALS

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Abstract

This study presents an integrated framework for slip identification (SI) and critical resolved shear stress (CRSS) determination in hexagonal close-packed (HCP) polycrystals, leveraging high-resolution digital image correlation (HRDIC) data. The methodology features two key advancements. First, an improved local gradient-based SI method is introduced, which modifies the objective function of the original Slip Systems based Local Identification of Plasticity (SSLIP) approach by incorporating a normalized slip resistance term derived from relative CRSS ratios. This corrects a kinematic ambiguity that caused overestimating activity in slip families with multiple systems. Second, a novel statistical method for CRSS determination is developed. By relating the mean absolute shear to the nominal resolved shear stress (RSS) across multiple grains, the method effectively averages out local stress heterogeneities, and a distinct activation threshold corresponding to the CRSS can be reliably identified. These procedures are then integrated into an iterative framework that simultaneously converges on slip activities and CRSS values. Validity of the methodology is confirmed through cross-validation with slip trace analysis, Schmid factor analysis, and crystal plasticity finite element (CPFE) simulations. This integrated approach offers a practical tool for understanding deformation mechanisms and developing high-fidelity constitutive models.

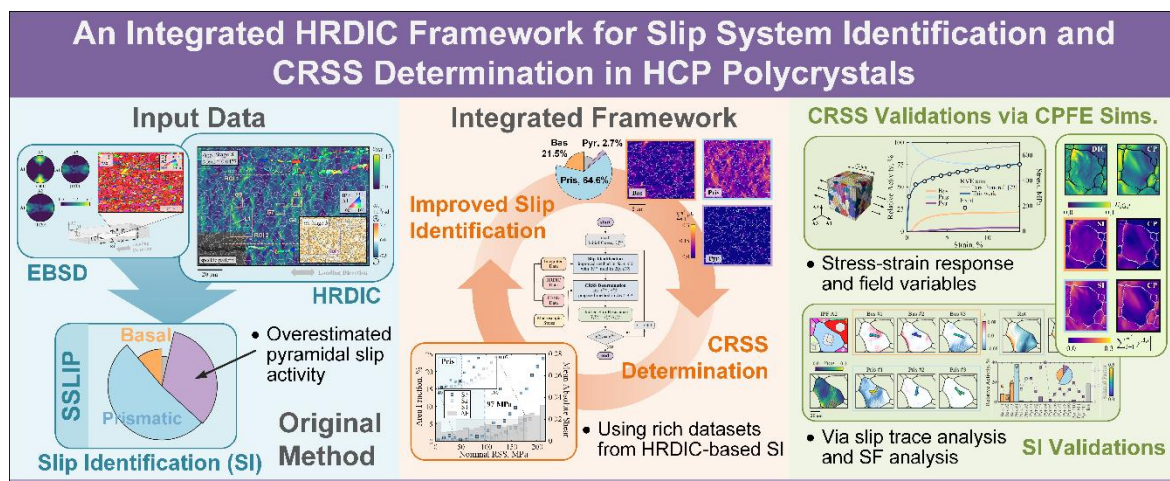


Figure 1. Graphic Abstract

Keywords: Hexagonal close-packed (HCP) materials; Slip system identification; Critical Resolved Shear Stress (CRSS); High-Resolution Digital Image Correlation (HRDIC); Crystal Plasticity

HIGH-TEMPERATURE MECHANICAL RESPONSE OF CO-FREE NON-EQUIATOMIC CrMnFe-Ni ALLOY

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Abstract

The equiatomic Cantor alloy CrMnFeCoNi is considered a reference high-entropy alloy due of its high strength, radiation resistance, and thermal stability, and suitability for structural applications. However, cobalt, which is added to stabilize the FCC phase and improve strength, produces long-lived radioactive isotopes under neutron irradiation and limits its use in nuclear systems. For this reason, development of Co-free alloys has become important. In this study, we investigated the non-equiatomic Cr₁₅Mn₁₃Fe₃₉Ni₃₃ alloy, designed within the INNUMAT project as a candidate for nuclear applications.

The aim was to examine its mechanical behavior in the temperature range 25–700 °C using a combination of experiments and molecular dynamics simulations. Tensile tests, SEM-EBSD, and XRD were applied to characterize phase stability, texture, and microstructure evolution. In parallel, atomistic simulations were used to follow dislocation activity, stacking fault formation, and twinning, and to compare the response of single- and polycrystals with experimental observations.

Results show that strength decreases with temperature due to thermally activated mechanisms and microstructural changes. Both experiments and simulations indicate the presence of stacking faults, twins, and grain boundary activity, with strong dependence on grain orientation ([111] grains soften gradually, while [110] grains lose strength rapidly above 550°C). The chemical design of the alloy, with no Co and higher Ni, raises the stacking fault energy and changes deformation mechanisms compared to the Cantor alloy. Despite the compositional complexity, Schmid's law remains valid in describing slip activity and anisotropic deformation.

The study confirms that Co-free HEAs are suitable for structural applications in nuclear environments by showing that they have favorable mechanical properties at high temperatures in addition to radiation resistance.

Keywords: Molecular Dynamics; HAEs, Co-free; Mechanical test; Microstructure.

Acknowledgement

Research was funded through the INNUMAT (Grant Agreement No. 101061241) and European Union Horizon 2020 research and innovation program under Grant Agreement No. 857470 and from the European Regional Development Fund under the program of the Foundation for Polish Science International Research Agenda PLUS, Grant No. MAB PLUS/2018/8, and the initiative of the Ministry of Science and Higher Education “Support for the activities of Centers of Excellence established in Poland under the Horizon 2020 program” under Agreement No. MEiN/2023/DIR/3795.

LIGHTWEIGHT AND HIGH-PRECISION BALANCED DEFECT DETECTION TECHNOLOGY FOR METAL PIPE WELDS

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Abstract

Defect detection of metal pipes is crucial for ensuring the safe operation of pipelines. Traditional detection methods often rely on manual inspection or detection algorithms based on conventional machine vision, which suffer from problems such as low detection efficiency and insufficient robustness. In recent years, deep learning technology has made remarkable progress in the field of object detection. Among them, the YOLO series models have been widely applied in industrial detection due to their fast detection speed and high accuracy. However, existing studies still face certain challenges when dealing with metal pipe defect detection, especially in the detection of multi-scale defects, where issues like missed detection and false detection are prone to occur, and the detection accuracy still needs to be improved. We propose an improved DSN-DETR model. Dual Aggregation Transformer Block (DTAB) is combined with C2f-Conv to reduce the training cost of the model. Inspired by PAFPN, we optimize the neck network of RT-DETR to improve the model's accuracy in small object detection. Finally, Normalized Wasserstein Distance (NWD) is adopted to replace the loss function of RT-DETR, thereby enhancing information fusion. Experimental comparisons were conducted on the defect detection dataset. The results show that the number of parameters of the DSN-DETR model is only 19,259,280, which is 3.1% lower than that of the RT-DETRr18 model; the mAP50 value reaches 0.915, which is 2.9% higher than that of the RT-DETRr18 model. This fully meets the requirements of lightweight and detection accuracy for circumferential weld defect detection.

Keywords: Metal pipe; Detection, Deep learning, RT-DETR, Multi-scale defects

Acknowledgement

This work was financially supported by the Natural Science Foundation of Hubei Province, China (2023AFC010)

FACET FORMATION MECHANISM AND BRIDGING BEHAVIOR IN HIGH-CYCLE AND VERY-HIGH-CYCLE FATIGUE OF METALLIC MATERIALS

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Abstract

In titanium alloys, the faceted morphologies associated with crack initiation are well-documented, particularly in the high-cycle and very-high-cycle fatigue (VHCF, failure cycle $N_f \geq 10^7$) under positive stress ratios $R > 0$. However, for austenitic materials with a face-centered cubic (FCC) lattice, such as stainless steels and nickel-based alloys, reports on fatigue faceting behavior remain relatively scarce. Here, as shown in Figure 1, using an additive manufacturing-fabricated nickel-based alloy (IN718) as the experimental subject, and by incorporating several research findings on titanium alloys, we conducted a systematic microstructural study on the common facet formation mechanism and its bridging behavior between these two types of alloys. Based on EBSD (electron backscatter diffraction) and TEM (transmission electron microscopy) characterizations, we established a theoretical model and furthermore provided prospects for simulations of crystal plasticity finite element method (CPFEM), dislocations, and molecular dynamics (MD).

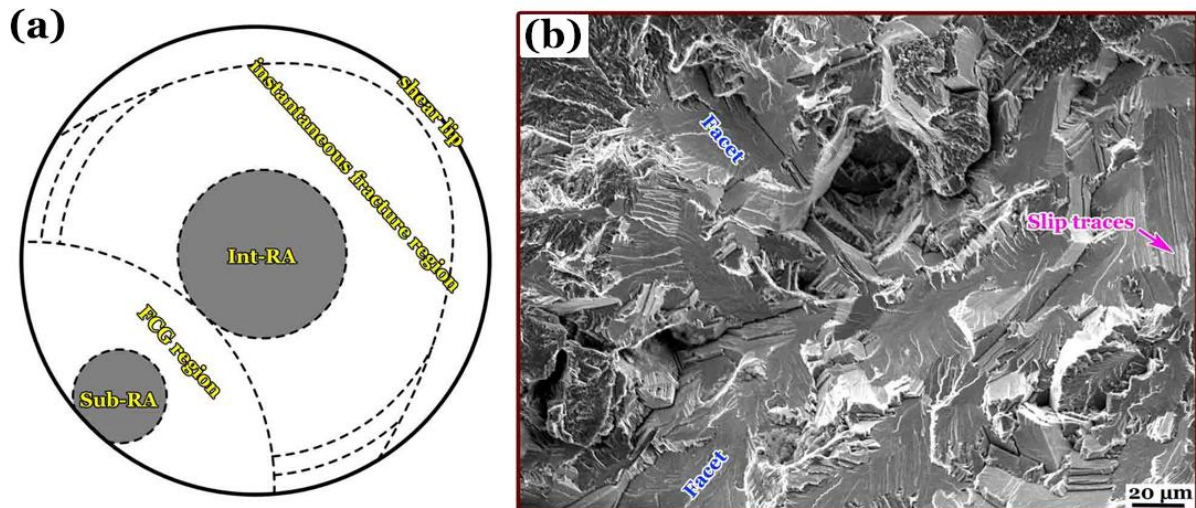


Figure 1. (a) Schematic diagram of fatigue fracture surface, (b) faceted morphology in crack initiation regions. Int-RA or Sub-RA denoting crack initiation regions at specimen interior or surface, FCG: fatigue crack growth.

Keywords: very-high-cycle fatigue; crack initiation; facet; titanium alloy; austenitic materials

STUDY ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF DISSIMILAR METAL WELDED JOINTS OF LARGE THICKNESS COPPER AND STAINLESS STEEL USING GTAW FILLED COPPER-IRON WIRE (Cu95%Fe5%)

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Abstract

The microstructure, mechanical properties, and iron-copper liquid phase separation phenomenon of the copper/stainless steel dissimilar welded joint were studied by using gas tungsten arc welding filled copper-iron alloy wire (Cu95%Fe5%) for T2 copper/SUS 304 stainless steel thick plate without preheating welding test. The results indicate that the formation of the weld microstructure is affected by the iron-copper liquid phase separation caused by the supercooling of the components in front of the solid-liquid interface. The weld contains Fe-rich dendrites and Fe-rich spheres resulting from the initial iron-copper liquid phase separation. Furthermore, the secondary iron-copper liquid phase separation phenomenon occurs within the large-sized Fe-rich spheres but not in the Fe-rich dendrites. As the iron content in the weld decreases, the size of the Fe-rich dendrites and the Fe-rich spheres reduces, and the number of secondary iron-copper liquid phase separation phenomenon and Fe-rich dendrites decreases gradually. The Fe-rich dendrites and the Fe-rich spheres in the weld act as the second phase and impede the movement of dislocations, which helps to enhance the strength of the weld. The location of the fracture in the welded joint during the tensile test is in the heat-affected zone on the copper side, and the tensile strength reached 233 MPa.

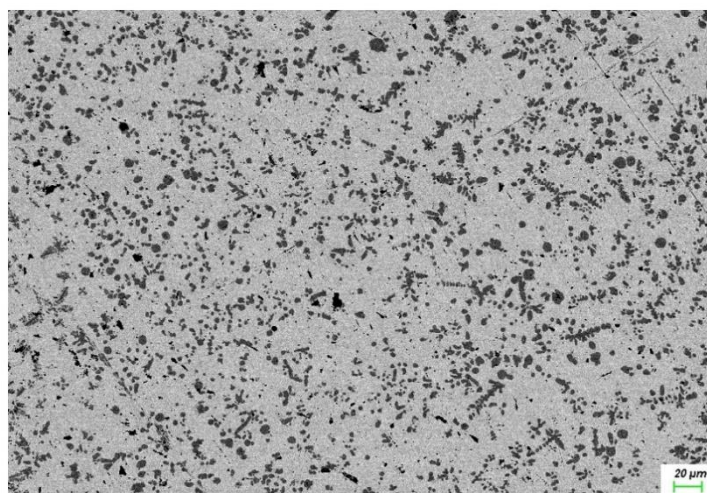


Figure 1. Iron-rich dendrites and iron-rich spheres in the weld seam

Keywords: copper-iron alloy wire; T2 copper; stainless steel; microstructure; Fe-rich dendrites; Fe-rich spheres

THE EFFECT OF LOADING ON STRESS DISTRIBUTION IN A MANDIBLE BONE

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Abstract

A mandible segment with natural teeth and dental implants was modelled in SolidWorks to construct two digital twins: one with coupled implants and the other featuring separated implants. These models were then used to develop Finite Element Method (FEM) models for calculating stresses and determining stress distribution under various loading conditions and material configurations. The idea is to evaluate all combinations of implant designs (coupled and separated), veneer materials (resin and porcelain), and loading conditions (single- and double-point load cases), to assess their influence on the stress response of the mandible bone segment. The results show that applying a two-point load significantly reduces the maximum stress within the mandible bone compared to a single-point load, highlighting the biomechanical advantage of distributed loading in implant-supported restorations.

Keywords: Digital twin; CAD model; mandible; natural teeth; dental implant

Acknowledgement

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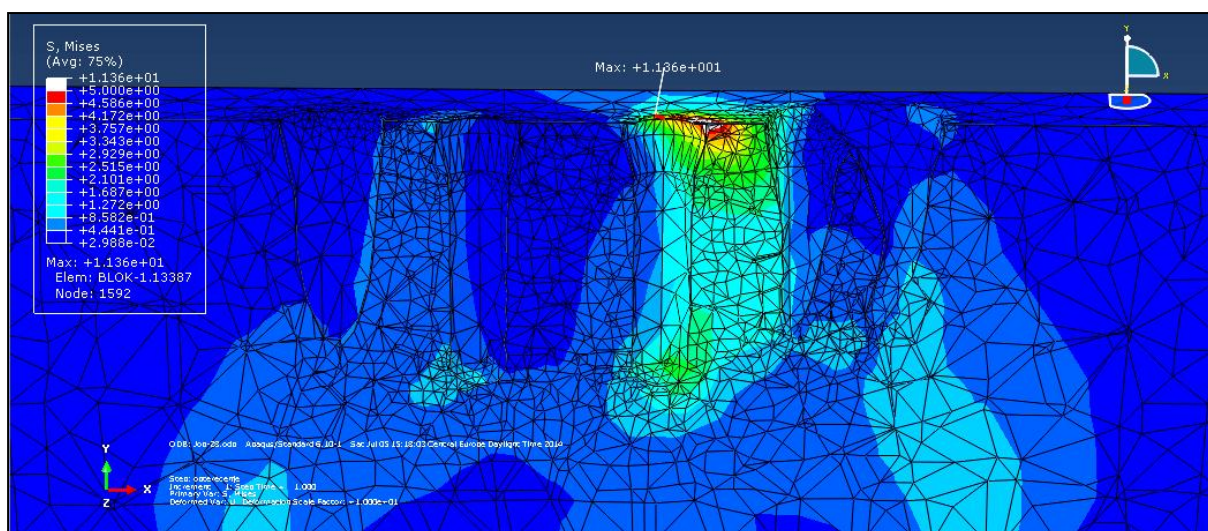


Figure 1. Example of von Mises stress distribution in mandible bone segment.

MULTIVARIANT ANALYSIS OF LABORATORY-RECONSTRUCTED HISTORICAL MORTARS

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Abstract

This study investigates laboratory-reconstructed historical mortars. Samples combined lime, sand, and a pozzolanic component. Fly ash from thermal power plants was included, known for its contribution to long-term durability. Analyses were conducted using X-ray fluorescence (XRF) to determine chemical composition, X-ray diffraction (XRD) for mineral phase identification, thermogravimetric analysis (TGA) to assess mass changes during heating, Fourier-transform infrared spectroscopy (FTIR) to monitor binder and pozzolan reactions, and petrography for microscopic characterization of aggregates and microstructure. Multivariate statistical methods, including principal component analysis (PCA), partial least squares regression (PLS), and self-organizing maps (SOM), were applied to identify factors affecting strength, porosity, and durability. Results show that fly ash addition reduces mortar porosity by approximately 15 % compared to the control sample without pozzolan and contributes to micro-crack self-healing, supporting development of restoration protocols compatible with historical structures.

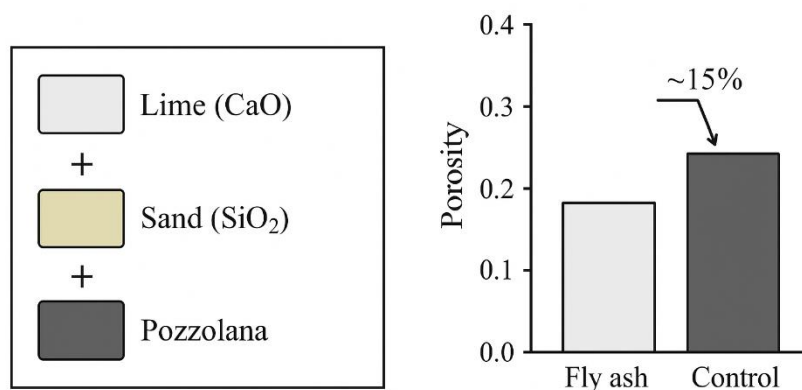


Figure 1. Workflow Diagram - Mortar Composition and Results

Keywords: Tribology; Wear; Gasoil; Vegetable oil; Four-ball wear testing machine

Acknowledgement

The authors of this study are grateful for the support from the Ministry of Education, Science and Technological Development of the Republic of Serbia, which provided the funds for this work (Contract No. 451-03-136/2025-03/ 200012).

DEVELOPING OF HEAT FLUX METER FOR FIRE RESISTANCE TEST

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Abstract

Fire resistance tests are important in the phase of a fully developed fire that starts in buildings and refers to structural, separate elements. Fire resistance of constructions could be determined in two ways: by calculation method or in standard test furnaces. In the standard furnace, according to the European standard EN 1363-1, there are following parameters like: temperature inside the furnace, temperature on the specimen measured on the non exposed side, and pressure in the furnace. In addition to these parameters, it would be important to have information about the value of heat flux through specimens. Heat flux through specimens represents the crucial parameter in the energy balance of the test furnace, and of course, the energy balance of the specimen. During the examination, the most important information, for the test specimen, is the temperature measured on the non exposed side, while heat flux through the specimens is still unknown. Heat flux value could be used as input for future numerical models exposed to fire. In this paper the developing of heat flux meter for the determination of heat transmittance through these constructions has been presented. The heat flux inside the furnace caused by radiation and convection has stochastic unpredictable nature. All of these processes are very fast and measuring of exact heat flux value is only possible with thin heat flux meters. The thick heat flux meters can measure the same but with increased delay time which is caused by heat flux meter inertia. This is the advantage of this type of heat flux meter because it creates smoother heat flux curve with lower noise than thin flux meter. The developed thick heat flux meter is a 1D conductive heat flux meter that works on the thermopile principle. Based on thermopile voltage value is possible for heat flux to be determined. The thermocouple K is also placed in the heat flux meter. The thermocouple type K has the temperature range -270°C to 1260°C , which records the exact temperature of the developed device. The validation and verification of this type of heat flux meter is divided into four phases. The first phase represents the fire resistance test of a wall made of hollow brick where the innovative heat flux meter was placed inside the hollow brick. In the second phase, the mathematical model based on the temperature difference of the conductive heat flux meter has been developed. In the third and fourth phase, the radiative heat source according to the standard EN 9239-1 has been used for verification of the performance of the developed heat flux meter. This device could be used for all types of furnaces. In the future the 2D and 3D heat flux meters would be developed. These flux meters could be used for determination of heat fluxes through all axes.

Keywords: Heat flux, heat flux meter, fire resistance, thermopile, developing of heat flux meter

Acknowledgement

The authors would like to thank the Ministry of Education, Science and technological development of the Republic of Serbia on financial support for research through Contract no. 451-03-136/2025-03/200012.

RESISTANCE OF FIRE IMPROVING OF STEEL ELEMENTS INSULATED BY FIRE PROTECTION MATERIAL

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Abstract

The use of wood in modern construction, due to its high mechanical properties, controlled quality, flexibility, durability, economy of application and a large selection of solutions in the design of buildings, steel is one of the most commonly used materials. In the event of a fire, in a very short time unprotected steel can reach a critical temperature at which it loses its stability and load-bearing capacity, which can cause the collapse of the structure and significant social and economic consequences. An unprotected steel support during a fire relatively quickly reaches a critical temperature, which is about 400°C, after which there is a loss of mechanical properties, progressive deformations, and then the collapse of part of the structure or the entire building. The deformation of the steel support is the result of a sudden decrease in the strength of the steel, which occurs already at 200°C, while at 400°C it drops to half of the initial value. Deformation of steel columns causes buckling and crushing; the beams bend and in some cases break, so after plastic bending, a part of the building or the building as a whole collapses. Depending on the type and quantity of combustible materials and ventilation conditions, a fire can have very different dynamics, thermal power and strength, which affects the thermal load of structures. For this reason, in order to avoid unwanted consequences, the steel elements of the structure need to be protected from fire, which is usually done with fire-resistant coatings, plates or plasters. In this paper the experimental and numerical analysis of three groups of the steel elements insulated by fire protection material are shown. The first group of samples consists of samples protected with systems based on fire boards type: AESTUVER thickness of 60 mm, the second group of samples consists of samples protected with systems based on fire boards type: FIREPANEL A1 thickness of 45 mm thick and the third group of samples consists of samples protected with systems based on fire boards type: AESTUVER 30 mm and 40 mm thick and with hard-pressed mineral stone wool 80 mm thick. All specimens have been exposed to standard fire test defined by the standard SRPS EN 1363-1. Experimental determination of fire resistance was performed in the standard vertical test furnace on ten samples according to the standards SRPS U.J1.042 and SRPS U.J1.043. The fire resistance was determined numerically according to the simple calculation models according to the standard EN 1993 part 1-2 for the samples which is unprotected and protected by fire protection material. The results obtained numerically and experimentally were compared. The significant deviation was obtained.

Keywords: Standard fire test; simple calculation models, insulated steel elements

Acknowledgement

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REUTILIZING RUBBER TIRE WASTE IN BUILDING INDUSTRY WITH IMPLEMENTATION OF NET ZERO PRINCIPLES: FROM WASTE TO ADVANCED MATERIALS

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Abstract

The rapid deterioration of concrete structures is often caused by flaws in structural design or by the improper selection of component materials. This study addresses the existing knowledge gap regarding the combined effect of frost and de-icing salts as a potential major cause of premature deterioration of concrete structures. The underlying concept is to mitigate concrete degradation by optimizing its mix design and incorporating waste resources (waste rubber tires – WRT) to achieve enhanced durability and resistance to aggressive environments. In this novel, tailor-made concrete, WRT is used as a substitute for air-entraining admixture. The objective is to establish a methodology for assessing the impact of WRT on the physico-mechanical and durability properties of concrete, as well as to identify the exact mechanisms by which WRT modifies and enhances rubberized concrete at the microstructural level. Fine WRT particles control structural water movement during freeze-thaw cycles, absorbing part of the internal stresses and resulting in a significantly more stable and durable material. The ductility of WRT particles, replacing fine aggregate, reduces concrete brittleness, while also balancing strains caused by ice expansion within the cement matrix pores, similar to the function of air voids in air-entrained concrete. To validate this hypothesis, three types of concrete were prepared: ordinary Portland concrete without admixtures (OPC), modified concrete with admixtures (superplasticizer Sika® ViscoCrete 4077 and air-entraining admixture Sika® Control 100 AER RS) (AER), and concrete with WRT (CRC). WRT with a grain size of 0/1 mm (manufacturer: Eco Recycling, Novi Sad) was used. Two parameters were varied in the mix design: water-to-cement ratio (0.40 and 0.50) and (in CRC) fine aggregate replacement (7.5% by volume). The replacement ratio was determined based on previous research where WRT (0.08–3 mm) was used as a partial sand replacement at weight ratios of 5, 10, and 15%. Specimen surfaces were exposed to 56 freeze-thaw cycles in the presence of de-icing salts. Results showed increased freeze-thaw resistance and reduced surface scaling for the concrete with 7.5% volumetric replacement of fine aggregate. Compared to the OPC control sample, this replacement increased the retained air content from 2.0% to 3.2% at the time of water addition. Air voids were predominantly located around rubber particles. The higher ductility of rubber grains compared to sand explains why WRT inclusion improved freeze-thaw resistance in the presence of salts—the ductility of the concrete increased, enabling the 7.5% WRT mix to exhibit lower mass loss due to surface scaling after freeze-thaw cycling. The outcomes of this study support the long-term management of WRT, the development of new utilization pathways for this waste, and the preservation of concrete performance robustness, while contributing to environmental protection in accordance with Net-zero principles. This approach can help scientists, engineers, policymakers, civil society, and other stakeholders (e.g., WRT manufacturers, environmental NGOs, trade associations, construction companies) to better understand the challenges and benefits of reusing waste rubber in concrete, as well as its impact on various performance metrics over the service life, thereby fostering the development of low-impact products that support waste-to-wealth concepts and the circular economy.



Keywords: Civil engineering; Recycling; Waste raw materials; Durability; Porosity

Acknowledgement

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CONCRETE BASED ON C&D WASTE FOR REDUCING URBAN HEAT ISLANDS

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Abstract

The trend of rapid global urbanization is one of the main aspects to be considered as a foundation for future sustainable civil engineering and urbanistic practice development. Currently, more than half of the world's population resides in cities. By 2050, that number is predicted to rise to 70%. Urbanization leads to environmental issues such as surface warming and air pollution. In the cities, these problems are caused predominantly by urban heat islands (UHI). The scientific and engineering community is currently dealing with issues such as a lack of afforestation, CO₂ emissions from the building industry, city-generated GHG emissions, UHI, and construction and demolition waste (C&DW). UHI results from characteristics of densely populated metropolitan regions, such as increased anthropogenic heat emissions, increased solar radiation absorption rate, decreased solar reflectance, decreased heat capacity, and decreased turbulent heat movement. The wider investigation is currently being conducted to target critical locations and to create an interactive map of UHI for the City of Belgrade. The goal of the here presented study is to design reflective material, i.e., concrete paver units based on C&DW with increased whiteness and improved Albedo effect. The concrete paving units (inorganic C&DW-based concrete - IWC) are prepared, tested, and subsequently, their design is optimized. C&DW has been frequently used in the production of paving units, however, there are very few publications that consider the influence of colour and albedo in such materials. The existing literature mostly relates to asphalt concrete while goal of this work is to produce normal-weight concrete units. The optimal IWC mix-design is obtained by varying w/c factor (0.4-0.55), filler content (10–30%), and filler type (pulverized tiles, stone, or sanitary elements), RCA content (0-50%), and additives (superplasticizers). Laboratory-scale testing on the samples includes: hydration mechanisms and mineralogical changes, microstructural characteristics, workability, slump test, density, depth of penetration of water under pressure, determination of rebound number, ultrasound pulse velocity, and mechanical strengths. The prolonged durability of the samples is assessed by testing the freeze-thaw cycles with or without the application of de-icing salts. Reflectometric characterization of samples is conducted according to ASTM C1549. The paver units' performances are in line with the EN and SRPS standards. Newly designed pavement units do more than 'consume' waste; they also lower ambient temperatures by enhancing reflectivity (albedo). The future work will include installing obtained paver units on the selected pilot UHI locations, monitoring and assessing the effect they have on decrease of the ambient temperature. In light of the urbanistic tendency of larger public spaces where biophilic design is difficult to integrate, this is a suitable answer for years to come. The AEC benefits the most (from a practical and scientific standpoint), since it obtains control of C&DW, reuses it, decreases CO₂ and GHG emissions, and keeps the expected temperature increase below 1.5°C, which is also in agreement with Net-zero objectives.



Keywords: Building materials; Concrete pavements; Urbanism; Recycling; Thermal Measurements.

Acknowledgement

This investigation is financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under Contract No.: 451-03-136/2025-03/ 200012. The goal of this work aligns with SDGs (especially SDGs 9, 11, 12, and 13).

COMPARISON OF PROPERTIES OF BUTT-WELDED JOINTS WITH AND WITHOUT MISALIGNMENT MADE OF HEAT- RESISTANT STEEL P91

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Abstract

This research provides a detailed investigation into the mechanical properties and microstructural evolution of butt-welded joints made of heat-resistant steel P91. The study addresses the influence of critical welding parameters, including preheating temperature, heat input, and post-weld heat treatment (PWHT), with a particular emphasis on the metallurgical consequences arising from the application of welding thermal cycles. Through the analysis of two welding probes initially welded pipes using the PH and PC (horizontal-vertical) welding positions. The research compares microstructure in the parent material (in this case P91), weld metal and heat-affected zone of welding joints with and without misalignment as artificially introduced defect. Furthermore, the research critically analyzes the influence of the complex thermal cycles experienced during the initial welding procedures to elucidate the practical application limits of this high-alloyed heat-resistant P91 steel in demanding service conditions.

Keywords: Heat-resistant steel P91; welding; heat input; mechanical properties; microstructural analysis; weld metal; heat affected zone; misalignment

Acknowledgement

This work is supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract No. 451-03-68/2024-14/200135 and. 451-03-68/2024-14/200213).

SEAWATER-INFLUENCED CHANGES IN QUASI-STATIC PERFORMANCE OF COMPOSITE SANDWICH STRUCTURES: A DATA-DRIVEN VALIDATION

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Abstract

Fibre-reinforced plastics (FRP) sandwich structures are often used in aerospace, biomedical, defense, and marine applications, where high structural performance is required to sustain complex in-service loads with reduced weight. In this paper, specimens made from plain-woven carbon-fiber-reinforced plastics (CFRP) and glass-fiber-reinforced plastics (GFRP) (both with epoxy matrix) as face sheets and laminates with polyvinylchloride (PVC) foam core were investigated. The specimens were subjected to sea water exposure with 3.5% salinity for 4 months, and moisture absorption was observed over the period. Tensile and flexural tests were conducted under a loading speed of 1 mm/min, and the force-displacement and stress-strain curves were analysed. A data-driven regression approach was employed to model the stress responses under different material types, test modes, and environmental exposures, enabling predictive insight into performance degradation mechanisms. The results revealed that seawater exposure for 16 weeks affected the mechanical properties of the samples as follows:

- Moisture absorption was 5.8%, 5.1%, 0.66%, and 1.79% for the CFRP sandwich, GFRP sandwich, CFRP laminates, and GFRP laminates, respectively, while the respective flexural samples recorded a moisture uptake of 5.15%, 4.82%, 1.64%, and 3.82%.
- Reduction in load by 31.20%, tensile stiffness by 38.57%, and elastic modulus by 14.46% for the CFRP sandwich, while the GFRP sandwich exhibited decreases in load, stiffness, and modulus of 26.85%, 30.08%, and 2.34%, respectively. It was shown that in tension, the effect of sandwich degradation was higher due to the decrease in bond strength between the face sheets and core.
- Exposure resulted in load by 15.1%, bending stiffness by 18.25%, and flexural modulus by 17.83% for the CFRP sandwich, while the respective parameters for GFRP sandwich were 24.20%, 24.23%, and 14.57%. Matrix hydrolysis leading to matrix crack, intralaminar/interlaminar delamination of face sheets, debonding, and fiber breakage was identified as the sequence of fracture events.
- Among tensile samples, the best predictive performance was observed in seawater-exposed CFRP using the XGBoost (R-Squared = 0.9937). In contrast, flexural samples yielded lower model accuracy, with Support Vector Regressor scoring 0.8460 on CFRP and AdaBoost achieving 0.8162 on GFRP, highlighting a higher predictability of tensile behavior compared to flexural response

Keywords: Fibre-reinforced polymers; quasi-static testing; moisture absorption; data-driven modeling

Acknowledgement

This work was supported by NISCO UK Research Centre.

METASTABLE, NANOLAMINATE, AND MULTI-PHASE STRUCTURES MULTIDIMENSIONAL STRENGTHENING COLD DRAWN PEARLITIC STEEL AND CRACK PROPAGATION RESISTANCE MECHANISM RESEARCH

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Abstract

This study investigates the microstructural evolution and multidimensional strengthening mechanisms of hypo eutectoid pearlitic steel with a carbon content of 0.81% during the cold drawing process. By analyzing the structural transformation of ferrite and cementite phases, the study characterizes the dynamic changes in pearlite colony size, interlamellar spacing, cementite morphology, and dislocation density at multiple scales. Based on the mechanical strengthening characteristics of cold-drawn pearlitic steel wire, the study identifies the main strengthening mechanisms as interface strengthening, dislocation strengthening, and solid solution strengthening, and quantitatively analyzes the effects of various strengthening mechanisms under different strain conditions, finding that the solid solution strengthening effect gradually increases when $\epsilon > 0.8$. Additionally, the cold-drawn wires exhibit typical structural features such as nanolaminate, metastable, and multi-phase. This study employs in situ tensile testing to investigate the crack propagation behavior of cold-drawn pearlitic steel wire, finding that the multiphase, nanoscale lamellar structure, and metastable phase can effectively achieve stress shielding and crack deflection, significantly enhancing the wire's resistance to crack propagation. This research provides a reference for the design of high-strength, high-ductility materials in advanced engineering applications, revealing potential methods for structural control of pearlitic steel wire and optimization of the drawing process performance.

Keywords: welding integrity; friction stir spot welding; FSSW; tensile strength; next generation aerospace

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MECHANICAL PROPERTIES ANALYSIS OF S355J0W WEATHERING STEEL REPAIR-WELDED JOINTS

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Abstract

Repair welding is crucial for maintaining and restoring the structural integrity of welded structures, ensuring they withstand operational stresses and environmental conditions. This research focuses on the mechanical properties analysis of repair-welded joints in S355J0W weathering steel. During the initial welding pass as well as the subsequent repair procedure, both the welded joint and adjacent material regions experience multiple thermal cycles. These cycles include: 1st welding, thermal cutting, carbon-arc gouging, and 2nd repair welding. The primary objective of this study is to investigate the effects of these repeated thermal exposures on the material's mechanical properties.

The methodology includes tensile testing with flat sheet specimens to evaluate the multiple reheated material region beneath the T joint (Figure 1a), while Mini Tensile Specimens (MTS) are used to assess the repair welded joint (Figure 1b). Hardness testing HV1 is performed as a supplementary method to analyze the effects of thermal exposure on the repaired weld (Figure 1b).

Flat sheet specimens revealed a significant strength decrease ($R_e = 300\text{--}337$ MPa vs. the 345 MPa minimum required by EN 10025-5, while $R_m \approx 470$ MPa) below the T joint, in the multiple reheated region. Ductility was also insufficient in most tested specimens ($A_5 = 10.4\text{--}19.1\%$ vs. 22% required). MTS testing showed adequate strengths ($R_e > 345$ MPa, $R_m > 470$ MPa) in the repaired welded joint. All hardness values in the repaired weld were ≤ 215 HV, meeting required limits. It can be concluded that the repair weld has the required mechanical properties, whereas carbon-arc gouging process reduces the material strength and should be replaced with a less invasive process (e.g. mechanical gouging).

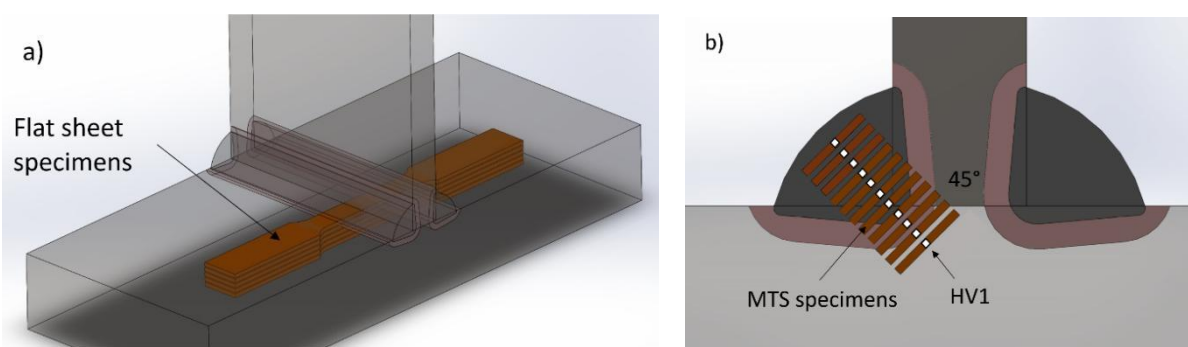


Figure 1. Mechanical testing: a) flat sheet tensile beneath the T joint; b) MTS+HV1 in the repaired weld

Keywords: repair-welded joint; weathering steel; heat affected zone; mechanical testing; mini tensile testing

FATIGUE LIFE PREDICTION FRAMEWORK FOR STEELS BASED ON MULTISCALE MODELLING OF CRACK GROWTH

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Abstract

In this study, we established a framework for predicting the fatigue life of ferritic steels using a multiscale modelling strategy. The multiscale model estimates total fatigue life from crack growth life alone, based on experimental facts.

The model consists of three sub-models: (i) macroscopic finite element analysis, (ii) microstructure, and (iii) crack growth. The input data required are microstructural information, tensile properties, and loading conditions, without any adjustable material constants. The macroscopic finite element analysis aims to define an active zone that includes all possible crack initiation areas and to obtain the strain amplitude field in this zone. For the microstructure model, we used a two-step 2D modelling strategy to represent surface and internal material features, considering actual fatigue crack initiation and growth behaviours. The Monte Carlo method simulates microstructure distribution, reflecting the natural scatter of fatigue life. In the crack growth model, we employed the interaction theory between cracks and grain boundaries, quantifying the driving force represented as the crack tip sliding displacement (CTSD) based on continuously distributed dislocation theory. All grains in the surface of the active zone are considered potential crack initiation sites, and the number of cycles to failure is determined using the weakest link assumption.

The model was strictly validated against experimental results from tests on three different steels under various loading conditions using four types of specimens. Despite the wide variation in experimental results, the predicted results showed good agreement with the experimental data. The model successfully reproduced the notch sensitivity of fatigue limits depending on material strength and accurately predicted the transition of the crack growth rate from the crack initiation to the long crack growth behaviour.

These findings demonstrate that the framework for predicting the fatigue life of ferritic steels was effectively established based on the multiscale modelling strategy simulating crack growth.

Keywords: Fatigue; Life prediction; Multiscale modelling; Small crack growth; Validation

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A MICROSCOPIC MODEL FOR SIMULATING GRAIN BOUNDARY DIFFUSION CREEP IN POLYCRYSTALLINE SOLIDS

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Abstract

Grain boundary diffusion creep, commonly referred to as Coble creep, is widely acknowledged as a key deformation mechanism governing the long-term creep behaviour of engineering components such as those used in power plants. However, direct laboratory testing under pure Coble creep conditions remains extremely difficult owing to the extended testing periods and specialised equipment required. Consequently, the development of a robust numerical framework capable of capturing this complex process offers a practical and powerful alternative for materials design.

In this study, a three-dimensional representative volume element (RVE) model is proposed to simulate creep deformation together with the nucleation and growth of voids driven by grain boundary diffusion in polycrystalline solids. The modelling framework consists of two coupled stages: deformation and void nucleation/growth. The deformation stage incorporates two sub-mechanisms—grain boundary (GB) migration and GB diffusion—while the subsequent stage evaluates void evolution based on the relative GB velocities and diffusional fluxes between neighbouring grain boundary facets (GBFs) computed in the deformation process. The rate of void nucleation is determined from the relative GB velocity, and the critical initial void size is obtained from the thermodynamic stability condition derived from Helmholtz free energy. Subsequent void growth is governed by atomistic diffusion along both the GBF and the surface of the voids.

Comparisons between model predictions of the void area fraction on 2D sections and experimental data for Alloy 201 (commercially pure Ni) revealed excellent quantitative agreement. Moreover, the simulation outcomes were consistent with classical theoretical relations, confirming the reliability and physical fidelity of the proposed approach.

Based on this validated framework, comprehensive numerical analyses were conducted to elucidate the influence of environmental conditions and polycrystalline morphology on Coble creep deformation and associated void evolution. The results provide a new quantitative foundation for the microstructure-based design of heat-resistant materials for advanced engineering applications.

Keywords: Grain boundary diffusional creep; Coble creep; Void nucleation/growth; Representative volume element; Micromechanics

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SIMULATION OF MULTI-CRACK FRACTURE IN BONE TISSUES AND BIOMIMETIC ADDITIVELY MANUFACTURED SCAFFOLDS

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Abstract

The study presents a comparative computational analysis of fracture behaviour in natural bone tissues and biomimetic porous structures, combining trabecular bone microarchitecture and additively manufactured scaffolds based on triply periodic minimal surfaces (TPMS). The extended finite element method (XFEM) coupled with the original multiple-crack algorithm was applied to representative volume elements (RVEs) of trabecular bone and polylactide (PLA) TPMS scaffolds under tensile and compressive loads. For trabecular bone, morphological effects on the stress redistribution and evolution of simultaneous cracks in individual ligaments were analysed through a clustering-based enrichment approach (see Fig. 1). For TPMS scaffolds (gyroid, gyroid variation, I-WP, and primitive), failure initiation and propagation were correlated with strain-concentration factors and experimentally determined fracture parameters of PLA. Both systems demonstrated strong morphology-dependent anisotropy of fracture response: trabecular bone resisted compression better than tension, while TPMS scaffolds exhibited earlier crack initiation in thinner ligaments and junctions. Quantitative criteria for crack-surface area and fracture volume fraction were introduced to describe damage evolution in heterogeneous porous domains. The results form a basis for unified modelling of multi-crack propagation in hierarchical porous materials, contributing to rational scaffold design for bone-tissue engineering and improved prediction of bone failure under physiological loading.

Keywords: fracture mechanics; porous biomaterials; trabecular bone; triply periodic minimal surfaces (TPMS); additive manufacturing

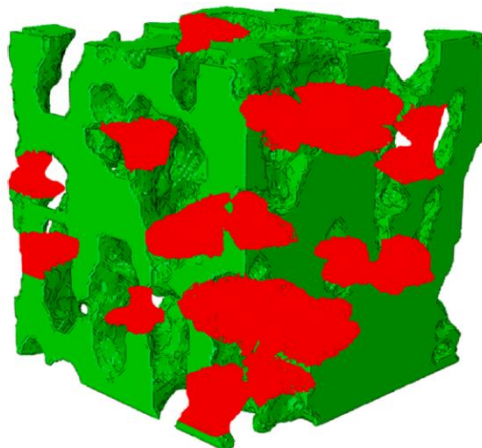


Figure 1. Location of clusters with cracks in a bone fragment

ATOMISTIC MODELING AND MECHANICAL PROPERTIES OF IRON HYDRIDE (FeH₄)

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Abstract

Iron hydrides and other potential hydrogen-iron compounds have garnered considerable interest recently. Overall, theoretical and computational studies of different hydrogen-iron compounds with complex hydrogen-material interactions are crucial for effectively shifting to a hydrogen-based and green economy. Recent computational studies based on ab initio calculations regarding hydrogen embrittlement (HE) in metallic materials verify the combined effects of HE mechanisms influenced by hydrogen concentration and various other factors [1-3]. The present data-driven study proposes a novel predicted iron-rich FeH₄ chemical system together with indications of a possible experimental synthesis at the atomistic level. Moreover, mechanical and elastic properties on the DFT level were investigated for the first time, which is important for a better understanding of complex hydrogen-metal interactions, including very complex hydrogen embrittlement phenomena in industrial steel.

Keywords

Iron hydride; DFT; FeH₄; Data mining; Mechanical properties

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DISCRETE DISLOCATION DYNAMICS HELPS INTERPRET HYDROGEN-PLASTICITY INTERACTIONS

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Abstract

The study of hydrogen embrittlement (HE) holds both scientific and technological significance, as hydrogen plays a crucial role in the development of a sustainable energy sector. HE occurs when hydrogen atoms penetrate materials, leading to degradation of their mechanical properties and premature failure. The hydrogen-enhanced localized plasticity (HELP) mechanism of hydrogen embrittlement emphasizes on the dominant role of hydrogen-dislocation interactions. The so-called discrete dislocation dynamics (DDD) approach has proven a useful tool to probe these interactions. With the approach, hydrogen-promoted dislocation multiplication and dislocation-mediated hydrogen diffusion and trapping have been captured. In the presence of hydrogen, an increase in dislocation generation is observed, which elevates stress concentration and makes the material more prone to failure; meanwhile, the hydrostatic stress fields exerted by dislocations alter hydrogen diffusion and trapping behaviors, deviating markedly from conventional model predictions. The work highlights the importance of incorporating plasticity considerations in the exploration of hydrogen storage in metallic materials.

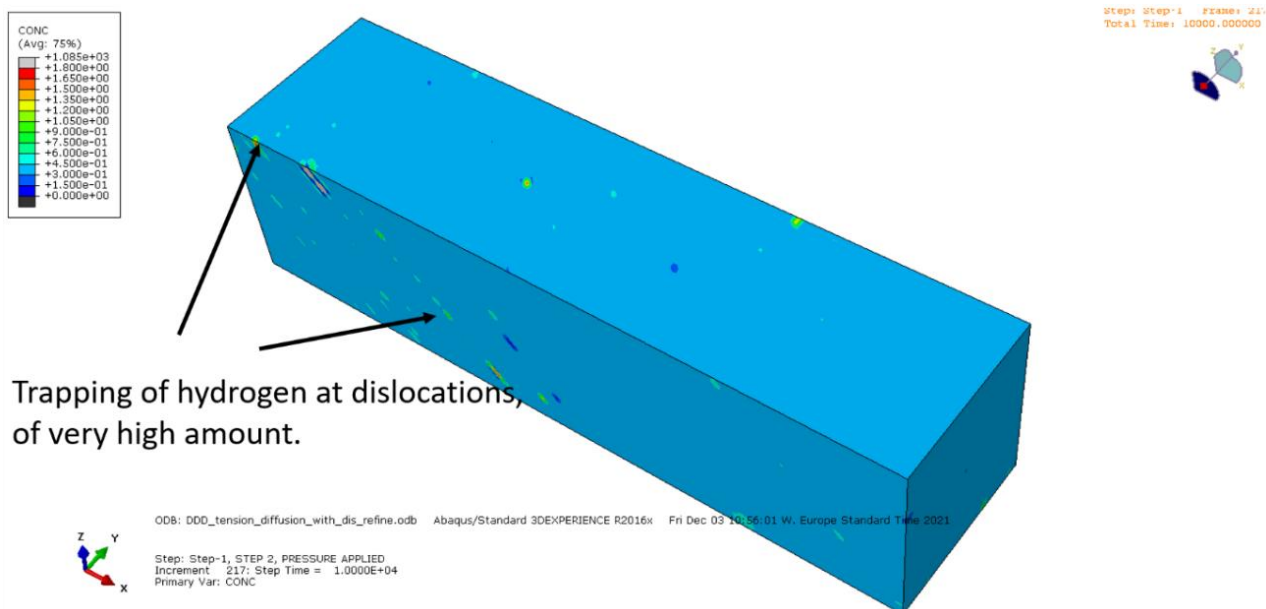


Figure 1. Discrete dislocation structure simulated explicitly as hydrogen trapping sites.

Keywords: Hydrogen embrittlement, plasticity, discrete dislocation dynamics, hydrogen diffusion

SMART HYBRID MATERIALS: MULTISCALE DAMAGE MODELING AND THE APPLICATION PROSPECTS FOR THE COLD CLIMATE

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Abstract

Hybrid composite materials, which structurally combine metal and plastic, dissimilar metals, or concrete and plastic reinforced with fibers or nanoparticles, have found wide application in recent years not only in aircraft construction but also in civil engineering, and in the repair and restoration of bridge structures. However, their use in extreme environment with cold climate is still extremely limited. Although hybrid materials have a higher strength-to-weight ratio and corrosion resistance compared to steel, they have disadvantages such as relatively high cost and brittle behavior during deformation at low temperature. Due to their internal porous structure, concrete composites and ceramics can accumulate damage in the form of microcracks when passing the freezing point of water and eventually deteriorate. By making them electrically conductive, the required temperature can be maintained through resistive heating to prevent water from freezing in the internal micropores. Furthermore, the structure and physical properties of concrete can be controlled by varying the amplitude, phase, and frequency of the current. In addition to meticulous experimental structural studies, mechanical and electrical testing, computer modeling is also crucial in studying such materials. Given their complex internal structure, it must take into account the multi-scale and multi-level nature of the processes occurring, as well as the phase transitions within the material. Furthermore, the complex environmental impact complicates the laboratory experiments, so the full-scale field testing of structures, components, and systems is required to account for scale factors. From this perspective, the creation of materials using polymer and graphene-containing fillers obtained from waste is of greatest interest. Composites reinforced with organic fibers and modified with graphene oxide at concentrations of up to 1% have shown promise. These hybrid composites have proven to be stronger under tension, more impact-resistant, harder, and heat-resistant. At modifier concentration above the optimal value, the mechanical properties of the composite are deteriorated. Multiscale stochastic modeling and visualization of the destruction process of new composite materials were carried out on the basis of microstructure parameters, using the concept of the pre-destruction zone for quasi-brittle materials. The fracture surface images were obtained by optical microscopy, SEM and STM methods.

Keywords: Hybrid material; concrete nanocomposite; structural size; pre-fracture zone; multiscale modeling

Acknowledgement

The work was supported by the Russian Science Foundation (24-21-20122).

PREDICTING CREEP RUPTURE IN AUSTENITIC STEELS WITH MECHANISM-BASED FUNDAMENTAL MODELS

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Abstract

Reliable long-term creep rupture prediction for high-temperature materials and structures is often limited by empirical models that lack a direct link to the underlying physical mechanisms of creep failure. This work utilizes a fundamental framework that predicts creep rupture based on physical principles without adjustable parameters. The framework comprehensively models both ductile and brittle creep rupture mechanisms. Ductile creep contributions, including solid solution hardening, precipitation hardening, and dislocation motion, are quantitatively determined. Key physical parameters are scientifically derived: precipitate evolution is simulated via thermodynamic computations and validated against experiments, while high-temperature elastic properties and atomic-size misfit are determined through first-principles calculations. Brittle creep rupture is modeled by considering creep cavitation along sliding grain boundaries, where grain boundary sliding (GBS) serves as the primary driver for cavity nucleation and growth in austenitic steels. A physically based GBS model, substantiated by a comprehensive analysis of 659 experimental data points spanning 12 material classes, is incorporated to model this behavior. The GBS model reveals that GBS displacement is linearly proportional to strain and grain size. By integrating these elements, nanoscale atomic size misfit from first-principles, microscale dislocation behavior and precipitate evolution from thermodynamic simulations, and relevant mesoscale creep theories, the resulting multiscale, mechanism-based fundamental models reliably predict the creep rupture in various austenitic steels.

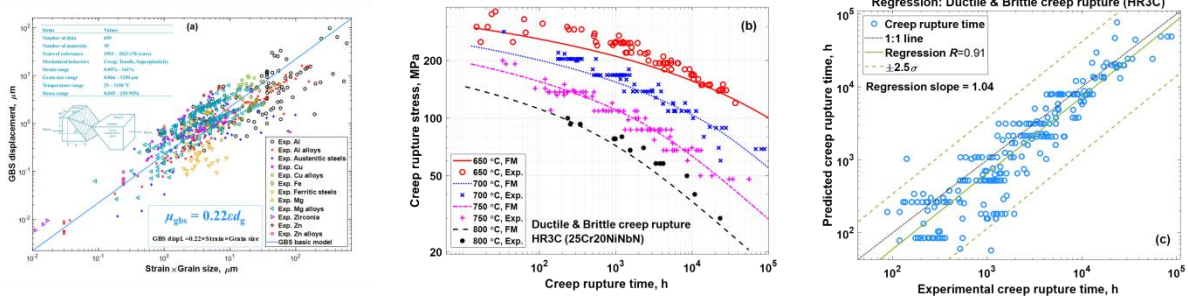


Figure 1. (a) Grain boundary sliding (GBS) models for various materials; (b) Creep rupture prediction of HR3C austenitic steels using fundamental creep models; (c) Regression analysis corresponding to (b).

Keywords: Creep rupture prediction; Austenitic steels; Grain boundary sliding; Multiscale modeling

Acknowledgement

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ADVANCES IN THE APPLICATION OF DIGITAL IMAGE CORRELATIONS FOR EVALUATING BOND STRENGTH BETWEEN PMMA TEETH AND DENTURE BASE

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Abstract

Failure resistance represents a key mechanical property determining the durability of artificial teeth used in acrylic dentures. This study aimed to examine the biomechanical behavior at the interface between PMMA teeth and the denture base under different loading angles. Real-time measurements of force, strain, and displacement were conducted using the Digital Image Correlation (DIC) technique. Three groups of samples were tested: teeth with an unmodified basal surface, sandblasted surfaces, and bases with retention holes. Each group was subjected to loading at 45° and 90°, simulating clinically relevant angles that correspond to mandibular movements during mastication. To assess the effect of material ageing, half of the specimens underwent artificial thermal ageing prior to testing. The results demonstrated clear differences in force response, strain distribution, and displacement patterns among the groups, indicating distinct biomechanical behavior. Both loading angle and surface treatment significantly affected the bond strength between the PMMA teeth and the denture base. Deformation was mainly localized in the incisal region, while the highest strain values were observed in the lower parts of the specimens. Thermal ageing did not show a statistically significant effect on fracture resistance. Overall, PMMA teeth with mechanically prepared bonding surfaces exhibited higher fracture resistance compared to unmodified samples. The use of DIC provided detailed, spatially resolved insight into strain and displacement fields, offering a better understanding of interfacial mechanics between PMMA teeth and the denture base.

Keywords: Digital Image Correlation (DIC); PMMA teeth; denture base; bond strength; fracture resistance

Acknowledgement

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EXPERIMENTAL STUDY OF HEAD AND NECK BIOMECHANICS UNDER IMPACT CONDITIONS WITH A PROTECTIVE HELMET

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Abstract

The development of advanced protective helmets represents a growing challenge in the fields of biomechanics and safety engineering. Modern helmet design extends beyond simple impact absorption, emphasizing instead the balanced distribution of mechanical loads across the head and cervical spine to minimize secondary injuries such as whiplash and vertebral trauma. In this regard, the present study provides an experimental investigation into the dynamic response of a protective helmet subjected to uppercut-type impacts directed toward three critical zones: the parietal region, the chin, and the cheek. A laboratory-scale physical model replicating the human head and neck was developed to evaluate helmet performance under realistic impact conditions. The study examined three distinct modes of helmet stabilization: tightly secured to the shoulders, loosely fastened, and completely free. Controlled impacts were applied to simulate uppercut strikes, while the ARAMIS optical deformation analysis system was employed for precise, non-contact measurements. This system enabled detailed monitoring of displacement fields, strain distribution, and acceleration behavior across the helmet and head surface, providing valuable insights into the complex mechanical interactions during impact events. The experimental results demonstrated that helmet fixation strongly affects the transmission and dissipation of impact forces. When rigidly attached, the helmet reduced localized deformation but significantly increased stress transfer toward the cervical spine. Conversely, the free condition allowed for greater head displacement but lower neck loading. These findings underline the necessity of optimizing helmet coupling mechanisms to achieve a balance between head protection and cervical safety. The outcomes of this research contribute to the design of next-generation helmets that combine enhanced skull protection with reduced biomechanical strain on the neck. Such integrated solutions are crucial for improving safety standards in fields such as combat sports, industrial protection, and military operations, where repetitive or high-energy impacts pose serious risks to the head and cervical region.

Keywords: protective helmet; uppercut impact; ARAMIS system; head; neck

Acknowledgement

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THE INFLUENCE OF LOW-CYCLE LOADS ON THE POSITION OF THE NEUTRAL LINE IN OBLIQUELY COMPRESSED REINFORCED CONCRETE ELEMENTS

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Abstract

The purpose of the work is the influence of low-cycle loads on the position of the neutral line in obliquely compressed reinforced concrete elements of rectangular cross-section.

Reinforced concrete columns were tested under low-cycle loads. They had dimensions of 11x16x300 cm.

Experimental specimens under oblique compression under low-cycle loads were tested in lever-type installations. The columns were centered along the geometric axis, and the eccentricity of the load application was taken to be the same and equal to $\varepsilon\omega\chi=28$ mm; $\varepsilon\omega\nu=33$ mm.

Strain gauges with measurement bases of 50 mm were used to measure the deformations of concrete and the position of the neutral line. They were placed in the column sections at distances $l_0/2$ and $l_0/4$ from the lower support. This arrangement of the sensors allows you to monitor the stress-strain state of reinforced concrete columns in one intermediate and in the most dangerous section in height during their testing. The condition of the strain gauges was monitored at each stage of manufacturing the experimental column specimens. The sensors on the concrete were placed in such a way that it was possible to determine the position of the neutral axis and the deformation of the most compressed concrete fibers, as well as to monitor the work of the stretched concrete near the neutral line.

The position of the neutral line in the cross-section of the obliquely compressed column specimens was determined using linear interpolation of the readings of the sensors located on the concrete. This method of determining the neutral line is the most traditional.

The test results confirmed that in all loading cycles the neutral line changed its position towards reducing the height of the compressed concrete zone, turning in one direction or another. In columns of all grades, the largest change in the area of the compressed zone occurred during the upper level load in the second cycle: in particular, in columns of the CC(0.3-0.6) grade, the area decreased by 4.6%; in CC(0.3-0.8) – by 5.9%; CC(0.3-0.6; 0.3-0.8) – by 8.3%. The angle of inclination of the neutral line remained practically unchanged.

In all columns, repeated low-cycle loads changed the position of the neutral line in the direction of reducing the area of the compressed concrete zone by 8 – 13%, moving with a turn in one direction or the other...

Keywords: reinforced concrete; column; oblique compression; low-cycle loads; neutral line

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HOW POLYANILINE MODIFIES CORROSION PATHWAYS AND ENHANCES CORROSION RESISTANCE OF MILD STEEL?

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Abstract

Mild steel's widespread use in industrial applications is hindered by its poor corrosion resistance, necessitating the application of protective coatings. While organic coatings are common, their long-term performance degrades due to blistering and delamination. To enhance protection, we developed composite coatings by incorporating 5 wt.% polyaniline (PANI) into commercial alkyd-based paint. PANI was synthesized in its emeraldine salt form, followed by deprotonation and reprotonation with various organic acids, resulting in materials with different doping levels and oxidation states that influenced their anticorrosive behavior.

Corrosion performance was evaluated via in situ measurements of dissolved iron concentrations in 3% NaCl solution using the ASTM 1,10-phenanthroline method, and corrosion current density was recalculated. The protective performance of the coatings was found to strongly depend on the initial oxidation state and doping level of the PANI used, revealing that the best resistance was achieved with PANI doped with sulfamic acid (doping degree 0.27). These composite coatings significantly reduced corrosion, blister formation, and delamination compared to the base coating. The primary degradation mechanisms of organic coatings involve pore formation, leading to rust and blistering. Conducting polymers such as PANI mitigate these effects by altering the oxygen reduction reaction pathway. Highly doped PANI primarily reduces oxygen to hydrogen peroxide anions (HO_2^-) rather than hydroxyl ions (OH^-), significantly lowering local pH and the likelihood of blister or delamination formation. Furthermore, hydrogen peroxide can react with Fe^{2+} ions to form passive Fe_2O_3 films, further enhancing corrosion resistance. Additionally, these coatings exhibit self-healing properties, offering prolonged protection even after mechanical damage. Despite challenges in appearance due to PANI agglomeration, their exceptional corrosion protection makes them suitable as primer layers for robust steel structures in harsh environments, such as bridges and industrial equipment. Our findings suggest that polyaniline-doped composite coatings can provide two to three times longer corrosion protection in chloride environments compared to base coating.

Future research endeavors ought to investigate strategies for mitigating the agglomeration of polyaniline (PANI) and further refining these coatings for expanded applications, thereby underscoring the promise of conducting polymers in the enhancement of corrosion protection technologies.

Keywords: self-healing coatings; polyaniline; corrosion; ASTM 1,10-phenanthroline method

Acknowledgement

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-136/2025-03/200135)

THEORETICAL FOUNDATIONS, BENEFITS, AND LIMITATIONS OF LASER SHOCK PEENING IN RUSSIA

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Abstract

Despite decades of research, metal fatigue remains an unpredictable phenomenon, responsible for major technological failures and substantial economic losses. Consequently, controlling fatigue crack initiation and propagation is of paramount practical importance. One highly effective approach is the generation of deep Compressive Residual Stresses (CRS). Laser Shock Peening (LSP) is an advanced surface treatment technique capable of inducing significant CRS to depths exceeding 1 mm. The process involves subjecting a metal surface to high-energy, nanosecond-duration laser pulses. This generates high-pressure plasma, leading to the propagation of elastic-plastic waves through the material. The resulting plastic deformation in the surface layer creates CRS with amplitudes as high as -1 GPa.

This study presents integrated theoretical and experimental investigations into CRS formation via LSP. The theoretical component addresses a set of coupled physico-mechanical phenomena, including laser-induced ablation, the propagation of nanosecond-scale elastic-plastic waves, and the subsequent computation of self-equilibrated residual stress fields. Particular emphasis is placed on analyzing the thermal conditions during LSP. It is demonstrated that, unlike other laser-based techniques, LSP does not cause material overheating or recrystallization.

An original experimental setup was developed to measure pressure pulse profiles in real-time and reconstruct the resulting through-thickness CRS distributions. This setup enables precise determination of the actual duration and amplitude of the pressure impulses generated during treatment. The established correlation between laser parameters and pressure pulses was utilized for process optimization and validation of the developed mathematical model.

Experimental results confirm that optimally calibrated LSP parameters can increase the fatigue life of notched specimens by several times. Conversely, improperly induced residual stresses can catastrophically reduce fatigue performance. This is illustrated by a case study on gigacycle fatigue regime, where the presence of significant tensile residual stresses in the specimen volume reduced the fatigue limit by three orders of magnitude.

Beyond fatigue life extension, LSP technology holds promise for other mechanical engineering applications. The report concludes with an analysis of its potential for improving the tribological properties under dry and boundary frictions.

Keywords: Laser shock peening; fatigue; gigacyclic fatigue regime; tribology

MEASUREMENTS AND SIMULATIONS TARGETING THE SETTLEMENT PHENOMENON OF SNOW COVER

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Abstract

This study conducted FEM simulation to mechanically represent the settlement phenomenon of snow loads for the purpose of analysing the settlement forces exerted on structures such as net fences and compared the results with the observed changes in snow depth. The observation site was selected in the heavy snowfall area of Ooshirakawa, Uonuma City, Niigata Prefecture, where the maximum snow depth exceeds 3 metres every year. The period of observation was December 2022 to March 2023. Furthermore, to set the period for comparison with FEM after the snowmelt season began, the analysis period was from 30 January 2023, when maximum snow depth occurred. During this simulation, we used a viscoelastic model as a settlement model for snow that responds to changes in time. Furthermore, the relationship between stress and strain was represented by the Maxwell model. In this compressible viscous model, viscosity changes with variations in temperature and density. Therefore, the initial density was set using data obtained from observations of cross-section, and the density was varied by calculating the stress from the viscosity computed based on the temperature change observed on site.

Figure 1 shows the comparison results between the measured snow depth over time and the simulation. Moreover, the figure also shows the daily average temperature variation of the observed values. From the figure, the simulation results accurately reproduce the observed data until 28 February, and therefore, the difference in values is increasing. Focusing on temperature changes, it can be seen that no days with temperatures below 0°C have occurred since 28 February, indicating a rise in temperatures. Therefore, it is thought that during this period, there has been much melting of snow in addition to the settling of snow. In this simulation model, the effect of snowmelt has not considered, which is thought to have caused the difference observed during this period. However, the factor exerting a mechanical influence on the deformation of net fence structures is not snowmelt, it is the settlement force generated by the compression of snow. In the future, we are planning to analyse the effects on net fence structures during periods when snowmelt has not occurred.

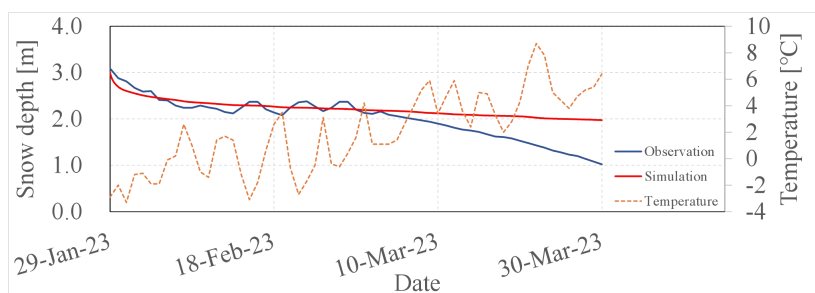


Figure 1. The comparison results between the measured snow depth over time and the simulation

Keywords: Snow cover; Net fence; FEM; Settlement force; Compressible viscous model

FINITE ELEMENT SIMULATION OF FLANGE SEALING STRUCTURE UNDER CYCLIC LOADING

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Abstract

This study investigates the sealing performance of gasket flange structures under cyclic thermo-mechanical loads using finite element analysis (FEA). Two advanced constitutive models, the Unified Visco-Plastic (UVP) and the Superposed Visco-Plasticity Creep (SVP), were implemented in ABAQUS to accurately simulate time-dependent gasket deformation. The analysis reveals that the unloading phase of a thermal cycle is the most critical period for leakage due to a rapid loss of gasket contact stress. Key findings indicate that a slow temperature loading rate of 0.01 K/s preserves sealing integrity by minimizing stress relaxation. Furthermore, an optimal flange thickness of 150-160 mm balances structural rigidity with gasket resilience, preventing excessive long-term deformation. The SVP model, which incorporates creep, proved more accurate for predicting long-term performance at high temperatures, underscoring the importance of accounting for creep in seal design.

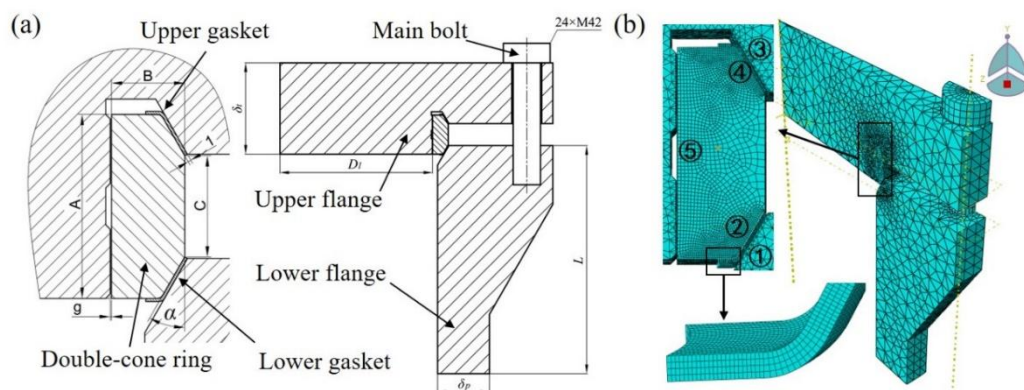


Figure 1. The double-cone seal structure: (a) 2-dimensional schematic; (b) meshes of the FEA model

Keywords: gasket flange structure; sealing performance; cyclic load; finite element analysis; constitutive model;

INVESTIGATION OF THE THERMAL AGEING EFFECTS ON WWER-1000 MATERIALS FOR UP TO 60 YEARS OF OPERATION

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Abstract

Ensuring long-term operation (LTO) and safe operation of Water-Water Energetic Reactor (WWER) is a key task of the nuclear power industry. One of the potential aspects to be considered for the LTO of Nuclear Power Plants (NPP) is the thermal ageing of the structural materials, which occurs under the influence of long exposure to elevated temperatures in the operating environment of reactor equipment. Thermal ageing can change the microstructure and mechanical properties of materials, which affects their crack resistance, impact strength, and overall reliability. Steel elements operating in areas with high temperatures and loads, such as reactor pressure vessel, primary circuit piping, and other critical components, require special attention. Studying the effects of ageing makes it possible to predict the residual life of structural elements and make timely decisions about their technical condition.

The goal of this work, as the part of the EU funded DELISA-LTO project, is to experimentally study the effect of thermal ageing on changes in the mechanical properties of structural steels used in WWER primary circuit up to 60 years of LTO in order to assess this effect for their service life.

The study involved structural materials taken from primary circuit components of WWER-1000 NPPs. Specifically, the investigated materials included:

- Main circulation piping in the initial state (10GN2MFA alloyed pearlitic steel);
- Steam generator collector in the initial state (10GN2MFA);
- Reactor flange fastening parts after 30 years of operation (alloyed Cr-Mo-V pearlitic steel 38KhN3MFA).

To simulate the material state after 60 years of operation, an accelerated thermal ageing approach was applied, involving elevated temperature exposure. Ageing was performed at a constant temperature of 450 °C, with durations ranging from 252 to 3465 hours, depending on the typical operational temperature of each component.

Mechanical testing included uniaxial tensile tests, Charpy-V notched (CVN) impact testing, and small punch tests (SPT) using miniature disc specimens of 8 mm diameter and 0.5 mm thickness, as well as hardness measurements. Based on the hardness values, mechanical properties such as ultimate tensile strength, yield strength, elongation, and reduction of area were estimated to support the evaluation of material degradation due to thermal ageing.

The results demonstrated that thermal ageing leads to changes in the mechanical behaviour of the studied materials. In all tested materials, a general trend of embrittlement was observed, as indicated by reduced CVN energy and increased susceptibility to brittle fracture. At the same time, an increase in tensile strength was recorded, suggesting material hardening. The combined embrittlement and strengthening phenomena highlight the importance of considering these parameters when assessing the residual service life and structural integrity of primary circuit components for LTO.



Keywords: WWER, thermal ageing; long term operation; mechanical properties

Acknowledgement

The presented work has been performed as a part of the DELISA-LTO project. DELISA-LTO has received funding from the Euratom research and training programme 2021-2025 under grant agreement No 101061201. The aim of the project is to determine the most affected and threatened components from the point of view of the LTO and describe the effect of the LTO on the material properties as well as develop a simulation tool able to predict the non-acceptable state of the material.

EFFECT OF PARAMETERS ON THERMAL STRESS IN TRANSPIRATION COOLING OF LEADING-EDGE WITH LAYERED GRADIENT

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Abstract

Transpiration cooling is an efficient thermal protection technique for the leading-edge of hypersonic aircraft. However, the local overheating of the transpiration cooling structure is prone to the defect of heat transfer deterioration, which seriously affects the life of the aircraft. In this paper, a transpiration cooling of leading-edge with layered gradient (TCS-LG3) is proposed to improve the uniform temperature distribution and high thermal stress. The thermal-structure coupling mechanism of TCS-LG3 is analyzed by using the CFD and orthogonal experimental. The results show that, compared with traditional transpiration cooling structure of leading-edge (TCS-T), the cooling performance (ξ) of TCS-LG3 is increased by 34.59-40.55%. The degrees that influence the average cooling efficiency (η_{ave}) and maximum principal stress (σ_{max} , principal) of TCS-LG3 are identified as the top layer diameter of porous medium and length of the porous medium, respectively. The optimal η_{ave} increased to 0.9196%, while the σ_{max} , principal decreased by 18.51%. The research results offer a reference for further analysis of the material selection and structure optimization in the transpiration cooling.

Keywords: Transpiration cooling; Layered gradient; Thermal-structure coupling

FATIGUE DESIGN OF ADDITIVE MANUFACTURING COMPONENTS: AN INTEGRATED FRAMEWORK COMBINING MACHINE LEARNING AND TOPOLOGY OPTIMIZATION

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Abstract

Additive Manufacturing (AM) technologies enable the production of components with complex shapes, which are generally designed with topology optimization (TO) algorithms. Within the TO design process, the stress in the component is commonly limited by considering the quasi-static material properties. However, cyclic loads are the most critical for structural components. This is particularly the case for AM components, as large manufacturing defects can form within the printed material, reducing fatigue performance, which is generally worse than that of conventionally manufactured parts and characterized by large variability. Accordingly, when TO algorithms are employed for the design of structural parts to be produced with AM processes, the stress should be limited by taking into account fatigue constraints. However, assessing the fatigue response and determining the corresponding allowable stress for AM components is challenging, as they strongly depend on the process parameters selected during manufacturing and require costly and time-consuming experimental campaigns.

In the present work, Machine Learning (ML) algorithms are developed to assess the allowable stress to be considered for the design with TO algorithms of parts to be produced with AM processes. The ML algorithm takes the AM process parameters as input and outputs the allowable stress, at the required reliability level, to be considered in the TO. A second algorithm is developed, and it outputs the critical defect size for a specific set of AM process parameters, with the allowable stress thereafter computed with a fracture mechanics approach. The proposed methodologies are validated with real components, proving their effectiveness and applicability.

Keywords: Fatigue; Machine Learning; Additive Manufacturing; Topology optimization; defects

HIGH-TEMPERATURE PERFORMANCE OF EX-SERVICE HP40-NB

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Abstract

The HP40-Nb alloy is a centrifugally cast austenitic steel that contains approximately 1.5% niobium. It is widely used in the petrochemical industry, particularly in reformer and pyrolysis furnace tubes, due to its high creep strength and oxidation resistance at elevated temperatures. However, prolonged exposure to extreme conditions can lead to microstructural degradation. This degradation involves the coarsening and precipitation of chromium and niobium carbides, loss of strengthening phases, weakening of grain boundaries, and the formation of voids and micro cracks. These changes lead to progressive embrittlement and a notable decrease in creep strength, which restricts the alloy's operational service life and raises the risk of premature failure.

This work focuses on approaches to prolonging the service life of HP40-Nb alloy tubes subjected to long-term high-temperature exposure.

The study examines samples from the HP40-Nb radiant tube used in a reformer furnace after 11.4 years of service, which have been additionally exposed to short-term overheating at 950, 1050, and 1150 °C for 2 and 8 hours. Microstructural changes were examined by optical microscopy, SEM/EDS, and XRD, while residual mechanical properties were evaluated through tensile and hardness tests.

Controlled heat treatments have been shown to reduce embrittlement, partially repair microstructural degradation, and recover mechanical strength. In particular, chromium carbide precipitation and redistribution, along with stabilization of grain boundary morphology, contributed to improved mechanical integrity.

The alloy HP40-Nb showed good tolerance to overheating within the 950–1050 °C range, where chromium carbide transformation and grain boundary reorientation enhanced creep resistance and mechanical performance, especially for exposures up to 120 minutes. Exceeding 1050 °C or prolonged exposure (over 120 min) within 950–1050 °C caused niobium carbide dissolution, increased brittleness, and the formation of microcracks and micropores, significantly reducing creep resistance and rendering the material unsuitable for high-temperature service.

The results indicated that some cases failed to meet the criteria, primarily due to large spans of stiffeners lacking transversal support. It was particularly the case with the port side deckhouse (larger structure and spans) in almost all loading and scantling cases, whilst the starboard deckhouse needed structural modifications in critical areas to satisfy the requirement.

Keywords: HP40-Nb alloy; short-term overheating; microstructure; secondary carbides; microcracks

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COUPLED ELECTROCHEMICAL-MECHANICAL DEGRADATION MECHANISMS OF SOLID OXIDE FUEL CELLS UNDER REDOX CONDITIONS

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Abstract

The instability of anode-supported solid oxide fuel cells (ASOFCs) during high-temperature reduction–oxidation (RedOx) cycling is a critical factor limiting long-term operation. In this study, the evolution of electrochemical and mechanical properties of ASOFCs under RedOx cycling was examined by electrochemical impedance spectroscopy, small-punch testing, and nanoindentation. Microstructural analysis was further employed to elucidate the degradation mechanisms. Results showed that the peak power density decreased by nearly 70% after five cycles. Quantification of degradation contributions indicated that ohmic resistance accounted for 69% of total performance loss, followed by hindered H₂ transport in the anode. Mechanically, flexural strength declined by nearly half, with the largest reduction during early cycles, while the elastic modulus and hardness decreased by 25.6% and 50.69%, respectively. SEM and EDS revealed that Ni particle migration and agglomeration led to a nearly fourfold increase in large particle-sized Ni clusters. Based on the driving role of Ni particle degradation in coupled electrochemical–mechanical processes, a theoretical model was developed to describe performance evolution. This work provides theoretical and experimental insights for extending ASOFC service life and improving engineering applicability.

Keywords: Solid oxide fuel cell; RedOx cycling; Electrochemical performance; Mechanical performance; Degradation mechanism

STAGING OF ADIABATIC SHEAR FAILURE AS CRITICAL DYNAMICS IN MICROSHEAR ENSEMBLES

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Abstract

This paper elaborates on the idea that one of the mechanisms of plastic strain localization in dynamically loaded materials occurs due to structural transitions in ensembles of microdefects. Samples were investigated during the dynamic tests in the split Hopkinson pressure bar and during the static tests on the Shimadzu AG X-Plus testing machine using the Photron FASTCAM SA-Z 2100K camera and the DIC technique. High-speed recording of strain field fluctuations and subsequent processing of their phase images were made to identify the stages of adiabatic shear-driven failure, caused by the development of collective modes of defect ensembles. Analysis provides evidence of a correlated behavior of defect ensembles, which can be classified as a structural transition leading to strain localization. The results of the experimental study show that one of the mechanisms of plastic deformation in the AMg6 alloy tested under dynamic loading conditions is driven by the jump-like processes taking place in the defective structure of this alloy.

Keywords: plastic strain localization; dynamic loading; evolution of the defect structure

Acknowledgement

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ON THE PREDICTION OF FATIGUE CRACK GROWTH IN ALUMINUM ALLOY WITH COMPRESSIVE RESIDUAL STRESSES USING THE WEIGHT FUNCTION METHOD

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Abstract

Residual stresses, commonly introduced during manufacturing and repair processes such as welding, play a critical role in the fatigue performance of structural components. Residual stress engineering offers the advantage of enhancing fatigue resistance without increasing weight. However, accurate prediction of the influence of residual stresses on fatigue crack growth (FCG) remains essential for damage-tolerant design and reliable repair strategies. This study focuses on thin AA2024 aluminum alloy specimens with residual stresses induced by laser shock peening (LSP) and laser heating (LH), as representative techniques of residual stress engineering. The weight function method is applied to evaluate the stress intensity factor (SIF) resulting from residual stresses. By superimposing the SIFs of applied loads and residual stresses, fatigue crack growth is predicted using Paris' law with an effective SIF that accounts for stress ratio variations. A particular emphasis is placed on the applicability of the weight function method in the presence of compressive residual stresses, where crack closure effects must be considered. The findings highlight that weight functions provide a powerful and efficient framework for predicting fatigue crack growth in thin specimens with residual stresses, provided that the stress gradients in the loading direction are moderate (Fig. 1). This work underlines the potential of the method to extend residual stress engineering approaches to complex scenarios, such as compressive residual stress fields typical of peening and certain welding processes.

Keywords: Laser shock peening; laser heating; residual stress; fatigue crack growth prediction; weight function

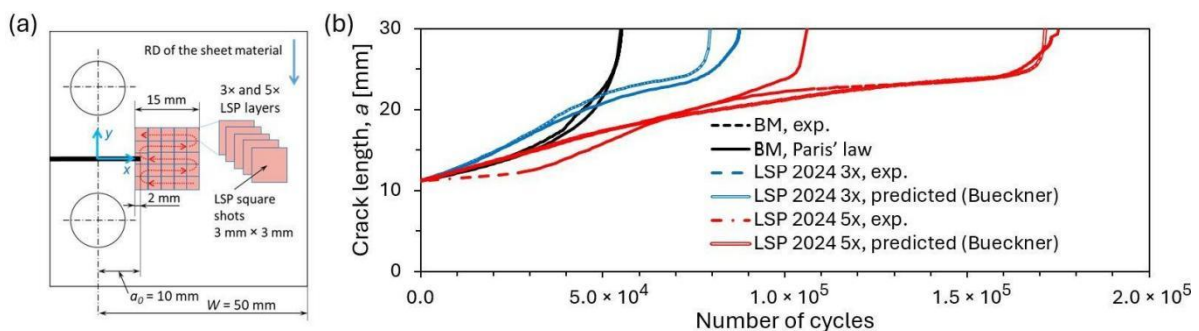


Figure 1. Schematic of the investigated C(T)50 specimen showing positions for double-sided LSP treatment, and (b) comparison of predicted and experimental FCG test results for base material (BM) and LSP-treated C(T) specimens.

THE IMPORTANCE OF PRACTICAL KNOWLEDGE IN DRAFTING, SURVEYING, SITE EXECUTION AND FIDIC RED BOOK FOR QUANTITY SURVEYORS

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Abstract

A Quantity Surveyor's effectiveness greatly improves when their technical knowledge is supported by practical field experience. Personal experience in technical drafting allows them to interpret construction drawings with greater clarity, which significantly enhances the accuracy of quantity take-offs during the preparation of Bills of Materials (BOQs). Similarly, direct involvement in surveying equips the Quantity Surveyor to calculate levels accurately and comprehend the scope of infrastructure works, leading to more reliable estimations. Moreover, a clear understanding of how construction activities are executed on-site enables them to perform realistic rate analyses, ensuring that labor, materials, and equipment costs are aligned with actual site conditions. This integrated knowledge makes the Quantity Surveyor not only a cost expert, but also a valuable link between design and execution. A Quantity Surveyor can enhance the accuracy and efficiency of their work by using advanced software tools such as AutoCAD Civil 3D, Microsoft Excel, Eagle Point tools and other advance software.

A Quantity Surveyor plays a critical role in ensuring that accurate budgets are established before tendering or contract award. Depending on the project scope, they either apply predefined rates or conduct detailed rate analysis based on materials, labor, equipment, and overheads. Accurate quantity extraction from drawings and proper interpretation of contract conditions (especially in FIDIC-based projects) are essential. If he knows drafting, he can read drawings accurately; if he knows surveying, he can calculate levels more precisely for quantity take-offs. If he understands site execution, he can prepare more accurate rate analyses; and if he knows FIDIC, he can draft clear contracts and contract documents. On the other hand, if a Quantity Surveyor does not understand the language of drawing lines, he will not calculate accurate quantities for claims. If he lacks knowledge of surveying, he will not properly understand utilities, sewer manholes, MEP manhole levels, and other essential data for quantity calculation. If he does not know the sequence of site execution, his claims will lack accuracy. And if he does not understand FIDIC, he will not interpret the contract correctly and may miss valid claims—causing losses to either the contractor or the client.

Keywords: Quantity Surveying; Drafting; Surveying; Site Execution; FIDIC

Acknowledgement

The author acknowledges the indirect technical exposure and project references from China Civil Engineering Construction Corporation (CCECC), DECON International Private Limited, Sajad Developer and Contractor, and Habib Rafiq (Pvt.) Ltd, which provided valuable insights contributing to the development of this independent research work.

ANALYSIS OF THE EFFECT OF UNDERCUTS IN MISALIGNED WELDED JOINTS

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Abstract

The goal of this paper was to investigate the effect of undercuts, combined with other welding defects, on the integrity of welded joints, and was inspired by previous work on the subject of welded joints with different defect combinations. Research presented here relied on the fracture mechanics principles, namely the Failure Assessment Diagrams (FADs), which was used to determine critical crack lengths, assuming a crack which had initiated in the weld face undercut, for two different cases, both of which had vertical plate misalignment as one of the defects.

Based on the obtained results, it was concluded that a crack in the undercuts was safe, showing good agreement with actual behaviour of misaligned specimens during tensile tests. Actual failure of specimens with such defect combinations, as determined by experimental and numerical means, would occur in the vicinity of other defects, such as incomplete root penetration.

Keywords: Welded joint defects; Failure Analysis Diagram; vertical misalignment; critical crack length

RISK ANALYSIS OF INLET PIPELINE IN HYDRO POWER PLANT PERUĆICA BASED ON FAILURE ANALYSIS DIAGRAM

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Abstract

Inlet pipeline in the Hydro power plant “Perućica” in Montenegro has been checked in 2024 by NDT methods with a focus on its branch and inlet elbows. In the lower and upper elbow of unit 7 indications have been detected during the first magnetic particle testing. At the lower elbow “A-side” a crack with length of 500 mm and depth up to 20 mm was detected, classified as unacceptable. Unacceptable defects were also found inside the upper welded joint in the pipeline branch, with length 150 mm and depth 7 mm, located at the mid-thickness from 14 mm to 21 mm. Having in mind potential catastrophic consequences in the case of a failure, the branch with defects was additionally analysed by means fracture mechanics parameters and structural integrity assessment to estimate risk of its further use. Although material in both cases was not very favourable from the fracture mechanics point of view, both defects turned out to be safe for further operation. This conclusion is also based on the fact that there is no mechanism of crack growth (practically no corrosion and fatigue). Anyhow, since the risk in the case of the inlet elbow was of relatively high level, repair welding was recommended and performed.

Keywords: Risk analysis; Fracture Mechanics; Structural Integrity; Inlet Pipeline; Hydro Power Plant

IDENTIFICATION OF CRACK INITIATION CAUSE IN SLEWING PLATFORM HORIZONTAL PLATE OF THE EXCAVATOR SCHRS630

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Abstract

A crack occurred on a lower horizontal plate of a slewing platform of bucket wheel excavator (BWE) SchRs630. Numerical calculation model of pylons, slewing platform and undercarriage was formed. Calculations were performed using finite element method (FEM) for different load cases in order to identify load that caused the crack. All the loadings repeat in cycles, particularly loading with inertial forces caused by bucket wheel boom and counterweight boom masses while breaking slew drive, and also a workload causing bending of pylons. All these loads cause (not high) stress concentration in this spot and could be the cause of a fatigue crack. To complete the whole picture of the structure behaviour dynamic analysis was performed. Simple redesign solution of this part of the structure was proposed.

Keywords: bucket wheel excavator SchRs630; slewing platform; (fatigue) crack; finite element method (FEM); static and dynamic analysis

Acknowledgement

This work is contribution to the Ministry of Science, Technological Development and Innovation of Serbia funded contracts no. 451-03-137/2025-03/ 200105 and 451-03-137/2025-03/ 200213 from 04.02.2025. and Serbian-Hungarian joint research project no. 9 (period 2024-2026) – Structural optimization of additively manufactured cellular titanium implant using artificial intelligence.

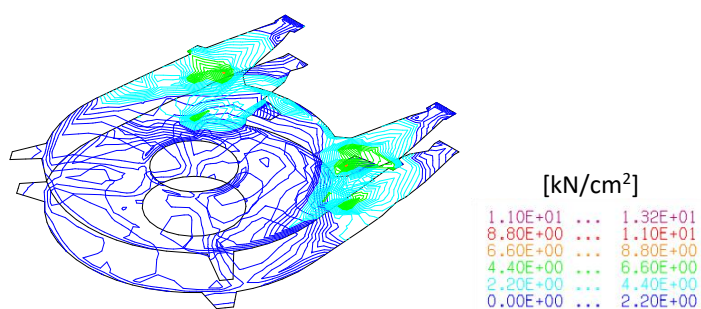


Figure 1. a) Slewing platform horizontal plates, workload, stress distribution (Note: 13.2 kN/cm² equals to 132 MPa), b) A crack on a lower horizontal plate of a slewing platform

TEMPERATURE CHANGE GENERATED LONGITUDINAL FRACTURE OF INHOMOGENEOUS BARS WITH FIXED SUPPORTS

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Abstract

Continuously inhomogeneous structural materials are characterized by smooth change of their properties in a solid. The most typical examples in this relation are the functionally graded materials which have a quickly growing use in a variety of structural applications in the up-to-date engineering. In many cases different continuously inhomogeneous structural members are subjected to temperature change that may have significant influence on the structural integrity. This paper aims to clarify how the longitudinal fracture of continuously inhomogeneous bars with fixed supports is affected by temperature change. In particular, we consider the bar shown in Figure 1. The cross-section of the bar is a circle. The material is continuously inhomogeneous along the cross-section radius. The bar has two portions with different radius. Besides, the bar hosts a longitudinal crack representing a circular cylindrical surface. Due to the fact that the bar is statically indeterminate structure (both supports of the bar are fixed), the temperature change to which the bar is subjected induces stresses that have influence on the longitudinal fracture. The problem of the strain energy release rate in the bar is solved. Since the bar has non-linear elastic behavior under temperature change, the complementary strain energy is used for deriving the strain energy release rate. A variety of graphs revealing the influence of the temperature change and other parameters of the bar model on the strain energy release rate are presented.

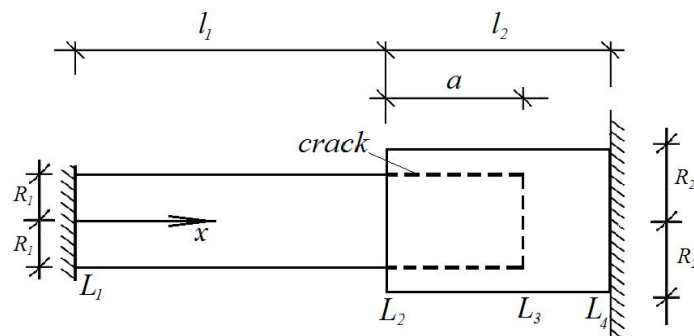


Figure 1. Bar with fixed supports

Keywords: Inhomogeneous bar; longitudinal fracture; temperature change; fixed supports

STUDY OF TANK FOR LIQUID WITH TAKING INTO ACCOUNT THE SUCCESSION OF FILLING-UP AND RUNNING OFF

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Abstract

Tanks are used for storage of liquids in numerous applications in various branches of up-to-date engineering. This fact indicates that analyzing different aspects of the mechanical behavior of tanks with liquids is an important problem from both theoretical and practical point of view. Our attention here is concentrated to the analysis of stresses and strains in the wall of tank for liquid with taking into account the succession of filling-up and running off. The tank under consideration represents a circular cylinder of thin wall (Figure 1). The bottom of the tank is placed on a rigid base. The top of tank is open. The tank has non-linear viscoelastic behavior. The wall of the tank is functionally graded (the material properties are distributed symmetrically with respect to the mid-surface of the wall). The viscoelastic behavior of the tank wall in the process of filling-up and running off is treated by using a non-linear stress-strain-time relationship that accounts for the stress history. This relationship expresses the total strain as a function of stress and time. The relationship in fact represents a sum of the elastic strain induced by the current stress value and the creep strain accumulated in the tank wall. The change of the strain in the tank wall with time is analyzed in detail. The effects of various geometrical and material parameters on the stress in the tank wall are also evaluated and illustrated by various graphs.

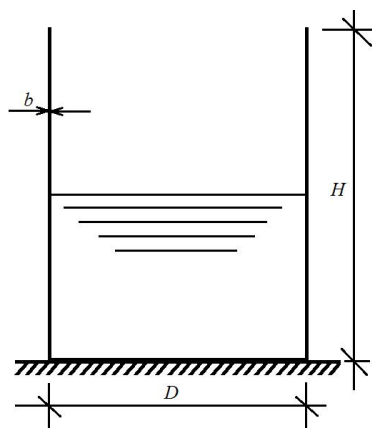


Figure 1. Tank with liquid

Keywords: Tank for liquid; non-linear viscoelastic behavior; filling-up and running off; stress

MULTILAYERED INHOMOGENEOUS VISCOELASTIC ROD MOVING IN VERTICAL DIRECTION: A DELAMINATION ANALYSIS

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Abstract

The rapid development in the field of multilayered inhomogeneous structural materials contributes for widening of their application in various sectors of modern engineering. The excellent properties of these materials make them an attractive alternative to traditional materials like metals and alloys in different engineering structures, mechanisms and devices. This paper is focused on delamination analysis of a multilayered inhomogeneous rod moving vertically upwards (Figure 1). The rod acceleration is known. Hence, the inertia loading acting on the moving rod can be determined by applying D'Alembert's principle. The inertia loading is distributed non-uniformly as a result of material inhomogeneity. The rod under the inertia loading has non-linear viscoelastic behavior that is treated by a model structured by linear as well as non-linear springs and dashpots. The rod is made by concentric layers having different material properties and thickness. There is a delamination crack between layers (the crack represents a circular cylindrical surface). The complementary strain energy in the rod is determined and used to obtain the strain energy release rate. The dependency of the strain energy release rate on the rod acceleration is investigated. The relation between the strain energy release rate and various parameters of the moving rod are studied and presented in form of graphs.

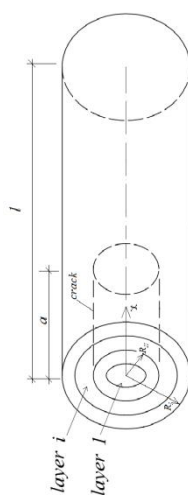


Figure 1. Multilayered rod moving vertically upwards

Keywords: Multilayered rod; inhomogeneous material; motion; delamination

RESEARCH ON ACOUSTIC EMISSION MONITORING TECHNOLOGY FOR INTERGRANULAR CORROSION OF 347H AUSTENITIC STAINLESS STEEL IN HIGH-TEMPERATURE MOLTEN SALT ENVIRONMENT

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Abstract

Taking the 347H austenitic stainless steel, the main material for the high-temperature molten salt storage tank of concentrated solar power (CSP) plants, as the research object, a high-temperature acoustic emission (AE) sensing device was designed. Acoustic emission monitoring experiments were conducted on non-sensitized specimens and sensitization pre-treated specimens in a molten salt environment at 565°C. The acoustic emission signal characteristics and state laws of 347H austenitic stainless steel under the influence of different pre-stress states were studied in detail. The results show that with the deepening of sensitization, 347H austenitic stainless steel exhibits increasingly obvious acoustic emission signal amplitude, energy value, and hit number. From the perspective of stress states, the more severe the sensitization state of the specimen, the more obvious the regularity of the acoustic emission signal characteristics with the increase of applied pre-stress. This is attributed to the promoting effect of pre-stress on intergranular corrosion and intergranular corrosion cracking under molten salt conditions.

Keywords: Molten salt storage tanks; austenitic stainless steel; intergranular corrosion; acoustic emission monitoring

Acknowledgement

The authors gratefully acknowledge the financial support for the present work from the National Key Research and Development Program of the P. R. China (2023YFF0614902), and Opening Project Fund of Materials Service Safety Assessment Facilities (MSAF-2024-116).

FLANGE MICRO-LEAKAGE JET FLOW FLUID-ACOUSTIC-STRUCTURE MULTI-FIELD COUPLING SIMULATION FOR ACOUSTIC EMISSION DETECTION TECHNOLOGY

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Abstract

The early detection of micro-leakages at flange connections is critical for the safety of industrial systems. However, the mechanisms of acoustic emission (AE) signals generated by micron-scale leakage channels are complex, and current research lacks a quantitative model correlating the flow field, acoustic field, and AE waves. This study proposes a multi-physics coupled numerical simulation approach, integrating large eddy simulation (LES), Lighthill's acoustic analogy theory, and elastic wave propagation theory to systematically investigate the flow field characteristics, acoustic field distribution, and structural vibration response of a micro-leakage jet from a flange. By establishing the transmission relationship between flow-induced noise near the leakage orifice and the elastic waves in the flange structure, a complete numerical mapping from fluid excitation to acoustic emission signals is achieved. Simulation and experimental results demonstrate that at a leakage rate of $2 \times 10^{-3} \text{ mg}/(\text{s} \cdot \text{mm})$, the peak frequency of the leakage AE signal received by the sensor is approximately 22 kHz, with a maximum voltage amplitude of 25.5 mV. the discrepancy from the simulated elastic wave amplitude is within 3.5 mV. Furthermore, the simulated and measured AE signals show agreement in both temporal attenuation trends and frequency-domain characteristics, validating the model's accuracy. This research can provide a theoretical foundation and an effective numerical simulation tool for AE-based monitoring of flange micro-leakages.

Keywords: Flange; Micro-leakage; Multi-Field Coupling; Acoustic emission

DATA ANALYSIS FOR STAMPING PRESS HEALTH MONITORING

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Abstract

Stamping presses play a crucial role in manufacturing due to their speed, precision, and repeatability. However, unplanned downtime caused by equipment faults can severely disrupt production and increase operational costs. While time-based preventive maintenance helps mitigate some risks, it may lead to unnecessary stoppages and fail to detect developing faults. Condition-based monitoring offers a more efficient alternative by assessing machine health and identifying early signs of component degradation, leading to improved cost efficiency, energy savings, productivity, and product quality.

In this work, a condition monitoring system is being developed in parallel with the design of a new servo-driven stamping press. The system integrates multi-sensor data from strategically placed sensors across the press structure to enable assessment of its condition while in operation. To evaluate potential monitoring approaches, acceleration data from several components of a recently manufactured press were acquired under different loading conditions. The data were analyzed in both the time and frequency domains: time-domain features were extracted to characterize signal behavior, while frequency-domain features were used to identify vibration modes through Operational Modal Analysis (OMA) techniques.

The study showed that each loading condition exhibits a distinct vibration signature, allowing the operating conditions of the press to be identified. These findings will support the development of algorithms for continuous acceleration data processing to monitor the press condition during operation. In parallel, a dashboard interface is being developed to visualize the condition assessment results and manage data processing, which will be incorporated into the final press system. Future work will focus on integrating additional data sources to further improve condition assessment accuracy and enable advanced predictive maintenance capabilities.

Keywords: Condition monitoring; Stamping press; Acceleration analysis; OMA

Acknowledgement

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CRITICAL COMPRESSION STRAIN OF GIRTH-WELDED PIPELINES WITH MISALIGNMENT

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Abstract

As a critical connection structure in large-diameter pipelines, girth welds may significantly influence the overall stability of the pipeline, particularly under the combination of internal pressure and bending. In this study, a three-dimensional numerical model is developed to systematically investigate the buckling behavior of girth-welded pipelines considering offset, unequal diameter, unequal wall thickness, and ovality misalignment. The influence of misalignment angle is analyzed, and mixed misalignment models are established to better simulate practical conditions. The results indicate that unequal thickness misalignment presents the highest risk among the investigated situations, leading to the greatest reduction in critical compression strain. Different misalignment types exhibit high sensitivity to angle variations and the buckling stability of offset and ovality misalignment improves with the misalignment angle increasing. The coupled interaction between geometric distribution and loading direction governs the mixed misalignment effects, with the combination of compression side offset misalignment and unequal thickness misalignment produces the highest risk, significantly reducing the bending capacity and accelerating buckling initiation. Comparative analysis reveals that the numerical results show highly agreement with the CRES prediction model, both revealing a decreasing trend in critical compressive strain with the increment of misalignment amplitude. Based on this consistency, the CRES model is modified by updating the FGI to apply the girth-welded pipelines with misalignment, and a new prediction model is proposed with fitting accuracy exceeding 97%. Furthermore, finite element simulations considering variations in D/t , internal pressure, and material hardening characteristics verifies the rationality of the FDP and FYT in the proposed model, with overall prediction error less than 9%.

Keywords: Girth-welded pipelines; Local buckling; Critical compression strain; Inequal thickness misalignment; Combined loads

FATIGUE DAMAGE MECHANISM IN HYGROTHERMALLY AGED CFRP: BASED ON IN-SITU DIC OBSERVATION AND SEM CHARACTERIZATION

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Abstract

The fatigue performance degradation mechanism of carbon fiber reinforced polymer (CFRP) in a wet and hot environment is complex, especially closely related to the ply angle. This study takes the fatigue behavior of $[\pm 45]_{12}$ and $[0/90]_{12}$ laminates as the research object, conducting high-stress (90% and 80% stress levels) fatigue mechanical experiments before and after wet and hot aging, and characterizing their fatigue failure mechanisms through in-situ DIC and SEM. The research found that although wet and hot aging led to resin plasticization and a decrease in interfacial strength, its impact on the fatigue performance of the two types of laminates was completely opposite. Due to a significant reduction in ultimate tensile strength (154%), the fatigue life of $[\pm 45]_{12}$ was significantly extended by approximately 500%, and the rate of stiffness degradation slowed down; while the ultimate tensile strength of $[0/90]_{12}$ only decreased by 8%, and its corresponding fatigue life decreased by approximately 15%, with an accelerated rate of stiffness degradation. Through DIC analysis of the stress-strain behavior, it was found that under fatigue loading, the high-strain zone of $[\pm 45]_{12}$ expanded from the middle to both ends, and the final fracture surface was in a swallowtail shape; while the high-strain zone of $[0/90]_{12}$ expanded from the edge to the interior, and the final fracture surface was relatively neat. Combined with SEM, it was found that $[\pm 45]_{12}$ was mainly subjected to shear stress, and resin plasticization to some extent relieved interlaminar stress concentration and delayed damage propagation; while $[0/90]_{12}$ was dominated by fiber stress, and interfacial weakening directly accelerated the initiation and propagation of fatigue damage. This study clearly identified that the ply angle is the decisive factor in regulating the fatigue behavior of CFRP in a wet and hot environment, providing an important basis for the fatigue-resistant design and life prediction of CFRP structures under wet and hot conditions.

Keywords: Damp-heat aging; Fatigue life; Stiffness loss; DIC characterization; Fatigue failure

CRACK PATTERNS AND STRENGTHENING OF HISTORICAL UNREINFORCED MASONRY STRUCTURES

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Abstract

Recognizing possible crack patterns, discontinuities, and brittle failure mechanisms in unreinforced masonry under seismic and gravitational forces enables effective retrofitting strategies. A wide array of traditional and modern materials and strengthening techniques offer compatible, removable, and sustainable conservation options. Steel and timber tie-rods are commonly employed to support the horizontal thrust of arches, vaults, and roofs, and are particularly effective in connecting structural elements such as masonry walls and floors. Additionally, composite reinforcement systems utilizing carbon and glass fibers along with thin mortar layers can enhance tensile capacity, ultimate strength, and displacement to prevent brittle shear failures.

This study provides an overview of masonry structural diagnostics and compares traditional with advanced strengthening methods for walls, arches, vaults, and columns. It also presents recent research on automated surface crack detection in unreinforced masonry (URM) walls, with an emphasis on machine learning and deep learning algorithms.

Keywords: Historical buildings, crack patterns, masonry structures

Acknowledgement

The results presented in this scientific paper have been partially obtained through the research activities within the project 2025-1-RO01-KA220-HED-000364478 Strengthening green and digital capacities in higher education through collaboration in integrating historical buildings into a sustainable and digital future, co-funded by the European Union under the program Erasmus+ KA220-HED program.

IMPACT OF THE WARM PRE-STRESS ON THE REACTOR PRESSURE VESSEL SAFETY MARGIN

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Abstract

Ensuring the long-term service life of reactor pressure vessels (RPVs) is one of the key aspects of nuclear power plant operation and safety. The lifetime of RPVs is strongly influenced by thermal and mechanical loading conditions, particularly those associated with pressurized thermal shock (PTS) events.

The application of the warm pre-stress (WPS) can play a significant role in ensuring the structural integrity of reactor pressure vessels (RPVs). Proper consideration of this phenomenon enables a more realistic evaluation of brittle fracture resistance and helps to avoid unnecessary overconservatism in safety assessment.

Over the past decades, several methodologies have been developed to incorporate the WPS effect into RPV integrity evaluations. The present work aims to assess the impact of WPS on the safety margins of RPVs and to compare the predictive capability of existing models and national approaches.

The paper is conceptually divided into two parts.

The first part focuses on analysing the efficiency of various WPS models in terms of their adequacy, predictive capability, and level of conservatism relatively to available experimental data. The objective of this analysis is to obtain an overall understanding of the predictive behaviour of the selected models and to identify their advantages, limitations, and areas requiring further improvement. The evaluation is mainly based on the existing Ukrainian WPS experimental data, data obtained from the international SMILE project, and other literature sources. Considered models include the modified Wallin, Chell & Haigh, and ACE (Areva-CEA-EDF) approaches, which were evaluated for their predictive reliability and applicability.

It can be concluded that all of the considered models demonstrate an adequate level of predictive capability for describing the WPS effect.

The second part of the work investigates the influence of different national WPS methodologies/standards on RPV integrity assessments. The impact of applying these methodologies is evaluated in comparison with the conventional tangent point approach.

For this analysis, the following national WPS approaches are considered: FAVOR (USA), ACE (France), KTA (Germany), Ukraine, Russian, Wallin and modified Wallin, VERLIFE, Chell & Haigh, NTD AME (Czech), and IAEA recommendations as well, representing almost World-Wide practices. Representative PTS scenarios for WWER reactors were selected to examine the behaviour of the various WPS approaches. In addition, to evaluate the effect of uncertainty, these PTS transients were modified to investigate whether small variations in loading parameters (such as K_{max} , K_{min} , and their ratio) could lead to significant changes on T_{ka} .

The comparative analysis provides a comprehensive overview of how different WPS methodologies influence the assessment outcomes and supports a further understanding of their practical applicability for RPV integrity evaluation. Open issues related to WPS implementation, identified within the EU-funded APAL (Advanced PTS Analysis for LTO) project, are mentioned.



Note, that the results of this study contribute to the ongoing efforts within international collaborations such as WPS CAPS (organized by the U.S. NRC) and the ETSON WGIAGE WPS Benchmark,

Keywords: pressurized thermal shock; warm pre-stress; fracture toughness; structural integrity

ENHANCING THE STRUCTURAL INTEGRITY OF HEAT-EXCHANGER TUBES AGAINST FLOW-INDUCED VIBRATION USING SURFACE TEXTURING

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Abstract

Flow-induced vibration frequently induces fretting wear between heat exchanger tubes and their support structures (e.g., anti-vibration bars), thereby compromising the structural integrity and operational safety of nuclear power systems. To mitigate this issue, this study proposes the application of laser surface texturing to enhance the wear resistance of anti-vibration bars. Micro-textures with various geometries and area densities were fabricated on the surface of anti-vibration bars using femtosecond laser processing. A series of impact wear tests were conducted in both water and air environments to evaluate the tribological performance under simulated service conditions. The results indicate that the water environment effectively suppresses stress concentration and delays wear penetration along the tube axis. Textured surfaces significantly reduced both contact forces and wear depth compared with smooth surfaces. In particular, circular dimples with an area density of 24.2% demonstrated the most superior performance, achieving a reduction in wear volume by 87.9%, a decrease in maximum boundary wear depth by 72.8%, and a reduction in average non-boundary wear depth by 67.0%. The primary wear mechanisms in water were identified as fatigue wear and oxidative wear, which differ from the fatigue-abrasive wear mechanism observed in air. A conversion coefficient of 0.5 was established to correlate wear volumes between the two environments. This study confirms that surface texturing serves as an effective strategy for extending the service life and enhancing the structural integrity of heat exchanger tubes in nuclear applications.

Keywords: Surface texturing; Flow-induced vibration; Heat-exchanger tubes; Fretting wear

THE INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE TECHNICAL CONDITION OF WOODEN STRUCTURES

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Abstract

The article presents the results of a study on the influence of various factors on the technical condition of wooden structures in existing buildings that have been in operation for an extended period of time.

Fluctuations in temperature and humidity, especially in load-bearing wooden roof structures, lead to the formation of longitudinal cracks caused by wood shrinkage. Based on field surveys and inspections of real structures, it was found that such defects were present in all examined buildings. It should be noted that both the size and number of cracks in wooden elements increased in cold (unheated) roofs. This can be explained by more abrupt temperature variations and differences throughout the service life of such elements. During the summer period, the attic space of roofs becomes significantly heated due to solar radiation, particularly when metal sheets (metal profiles or metal tiles) are used as roofing materials, while in the cold season, it undergoes rapid cooling.

Daily temperature fluctuations lead to the formation of condensation moisture on roof structures. Numerous cases of improper installation or fastening of waterproofing membranes have been identified, resulting in the partial wetting of rafters. Under conditions of insufficient ventilation and the absence of dormer windows or natural lighting, condensation moisture accumulates, leading to the development of fungi and mold on wooden structures. In the short term, such roofs begin to exhibit processes of wood decay. As a result, roofs with a service life of less than ten years may require repair or replacement. It is worth noting that during the study, wooden roof structures with a service life of approximately 100 years were also identified. In these cases, a proper ventilation regime was maintained, ensuring a satisfactory technical condition of the wooden elements. The absence of adequate ventilation also negatively affects other structural components of the buildings under investigation.

Systematic wetting of wooden elements in operated buildings also has a detrimental effect on their technical condition. The presence of moisture ingress into wooden structures eventually leads to wood decay. However, under normal ventilation conditions, decay caused by moisture penetration develops much more slowly compared to elements lacking ventilation and natural lighting.

The conducted study of in-service wooden structures has demonstrated that the temperature–humidity and ventilation regimes during operation have a significant impact on their technical condition. When these regimes are violated, a considerable portion of wooden structures become unsuitable for normal operation, and their residual service life is substantially reduced.

Keywords: wooden structures; serviceability; crack; technical condition; defect

CARBON NETWORK FORMATION INDUCED BY PAPER FIBERS GREATLY IMPROVE CARBON-CEMENT SUPERCAPACITOR PERFORMANCE

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Abstract

Cement-based structured supercapacitors are promising candidates for large-scale energy storage in renewable energy applications due to their versatility and scalability. However, significant challenges remain in achieving an optimal balance between mechanical strength and electrochemical performance in carbon-cement supercapacitors. Herein, paper fibers are incorporated into the carbon cement, enabling a low dosage of nanocarbon blacks to form a conductive carbon network. This strategy significantly improves the electrochemical properties without compromising mechanical strength. Notably, the nanocarbon black utilization of the carbon content as low as 5% carbon content have increased from 1.49% to 98.39%, while the compressive strength attained 29.46 MPa, and this significantly reduces the cost of raw materials for carbon cement. These values meet the requirements of most application scenarios, offering significant potential for the integration of carbon-cement supercapacitors in civil infrastructure and other large-scale applications.

Keywords: Airflow; flow visualization; fluid dynamics; smoke wire

Acknowledgement

energy storage; supercapacitor; carbon cement composite; paper fiber; electrochemical and mechanical properties

ARTIFICIAL INTELLIGENCE AND BIG DATA

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- W. Yang, Z. Li, Y. Chen, Y. Li - *Multiscale Homogenization Method for the Electromechanical Coupling of Porous Viscoelastic Nanocomposites*
- N.I. Sidnyaev, E.E. Sineva - *Artificial intelligence methods for assessing the fracture toughness of materials in a high-temperature space environment*
- Y. Han, W. Tian, B. An, D. Song, K. Wang - *Machine Learning-driven Insights into the design of BaFeO₃-Based Perovskite cathodes for solid oxide fuel cells*
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- H. Fagersand, K. M. Mathisen, D. Morin, J. He, Z. Zhang - *LSTM prediction of temperature evolution in wire-arc additive manufacturing*
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- I. Didych, O. Yasniy, D. Tymoshchuk, O. Holotenko, V. Boichun - *Comparative analysis of the accuracy of neural network and analytical methods in modelling fatigue fracture of titanium alloy*
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- L. Wang, Y. Meng, X. Yang - *Numerical and experimental study on flow loss reduction effect of micro-textured surface*
- Q. Chen, H. Wang, X. Ma, Y. Zhu - *Bayesian deep learning framework for dual uncertainty quantification in corrosion fatigue life prediction*
- M. Laurenti, J. Tirillo, F. Sarasini, F. Berto - *Enhancing structural integrity of SLA 3D-printed lattices via AI-based mechanical response optimization*

ML BASED SOLUTION OF SOLID MECHANICS TASKS

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Abstract

Machine Learning (ML) and Neural Networks (NN) have proven to be highly versatile and applicable to a broad variety of engineering problems in solid mechanics [1, 2]. The present talk gives an overview of recent trends in this field and shows some application examples.

Example 1: The phasefield-based crack simulation is easy to implement into an ML setup due to the inherently energy-based nature of the problem. However, to avoid divergence and overfitting behavior during training, the conventional techniques requires a very high number of collocation points which is further intensified in cases where the necessary NN expressivity is elevated to model discontinuities such as cracks. The work proposes Quadrature-Based Deep Energy Method (Q-DEM) employing a mesh-based discretization analogous to variational Physics Informed NNs (V-PINNs). The method is validated by a case study on a plate made of Al 7075-T6 subjected to traction loading leading to a mixed mode I-II fracture.

Example 2: A new ML architecture, namely the oscillatory Physics-Informed Neural Network (oPINN) has been suggested for the numerical investigation of oscillating continua [3]. The approach carries out a modal analysis of a structure alongside with the transient analysis. Moreover, the potential of transfer learning has been investigated. This step results in a better accuracy and allows to speed up the calculations for a series of related tasks exploiting the similarity between neighbouring solutions and the adaptive nature of NN training. Among others, the numerical results show the great efficiency of the procedure in calculating solutions for comparatively stiff problems.

Example 3: The final example deals with the statistical homogenization methods evaluating the effective response of heterogeneous materials to different cases of loading. A key challenge in applying these methods is the choice of a suitable probability function that accurately captures the material's spatial correlations [4]. By coupling fully connected neural networks (FCNN) and a convolutional neural network (CNN), both trained simultaneously, our adaptable approach significantly reduces the data requirements, allowing for effective training with a comparably small data set.

Keywords: Machine Learning; Physics Informed; Neural Networks; Damage; Oscillations; Composites

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MULTISCALE HOMOGENIZATION METHOD FOR THE ELECTROMECHANICAL COUPLING OF POROUS VISCOELASTIC NANOCOMPOSITES

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Abstract

Porous nanocomposites, due to the flexible tunability of their microstructures, offer precise control over the material's stiffness and sensitivity to external mechanical stimuli, making them highly advantageous in the design of sensitive layers for flexible sensors. However, the inherent viscoelastic properties of the matrix material significantly influence the overall electromechanical response under both static and dynamic loading conditions, leading to reduced accuracy and stability in the output signals of flexible sensors. Therefore, understanding the coupling effects between material viscoelasticity and microstructure, and their impact on the electromechanical response of porous nanocomposites, has become one of the key scientific challenges in flexible sensor design. To address this issue, this study proposes a multiscale electromechanical homogenization method that accurately establishes a quantitative correlation model between the material's microstructure and its macroscopic viscoelastic electromechanical response. The model considers the pore evolution characteristics in the porous structure, enabling effective capture of the dynamic and static loading and unloading response characteristics of porous nanocomposites under different mechanical conditions. The proposed model has been validated through both experiments and simulations, demonstrating good accuracy and effectiveness. Furthermore, parameter analysis of the theoretical model reveals the specific influence of viscoelasticity on the accuracy, stability, and hysteresis of the electromechanical response of porous nanocomposites, providing a theoretical foundation and effective guidance for the design and optimization of high-performance flexible sensor materials.

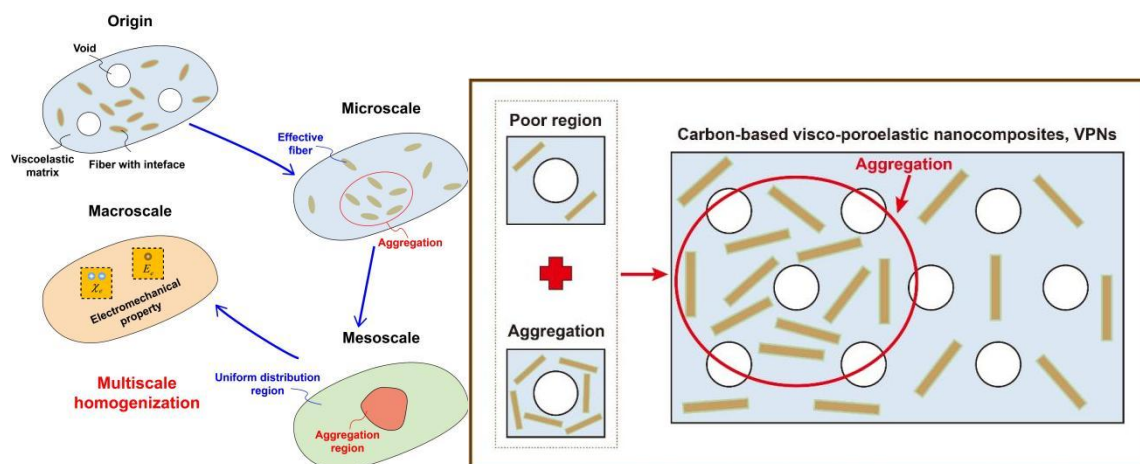


Figure 1. Schematic diagram of multiscale constitutive homogenization method.

Keywords: Porous viscoelastic nanocomposites; Flexible sensors; Multiscale homogenization; Viscoelasticity; Electromechanical coupling

ARTIFICIAL INTELLIGENCE METHODS FOR ASSESSING THE FRACTURE TOUGHNESS OF MATERIALS IN A HIGH-TEMPERATURE SPACE ENVIRONMENT

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Abstract

Given the increasing technogenic load on spacecraft, enhancing their reliability and durability is a pressing task. One of the key factors affecting the structural integrity of spacecraft, is the impact interaction with microparticles of cosmic dust and technogenic debris, leading to crack formation, erosion, and catastrophic failures. Particles smaller than 1 mm are particularly hazardous, as their impact has not been sufficiently studied.

This paper proposes an approach to integrate artificial intelligence (AI) methods and expert systems for predicting the fracture toughness of refractory materials, such as tungsten and titanium alloys, under high-velocity impact conditions. Based on formal grammars, ontological models, and semantic analysis, an approach for creating a knowledge base is proposed to automate the process of assessing material resistance to dynamic loads.

The use of predicate models and frame representations allows for the formalization of knowledge about the mechanical properties of materials, their operating conditions, and the nature of damage. A methodology for assessing the critical stress intensity factor using small-scale specimens is proposed, reducing the costs of experimental research.

The described expert system supports decision-making in selecting materials and structural solutions for spacecraft protection and allows for the optimization of parameters of multilayer nanostructured coatings aimed at dissipating impact energy and suppressing microcracks.

It is shown that the integration of AI methods and materials science analysis enhances the accuracy of predicting the service life of spacecraft structures and reduces the risks of their failure under extreme temperatures and impact loads.

Keywords: Fracture toughness; expert systems; artificial intelligence; spacecraft

MACHINE LEARNING–DRIVEN INSIGHTS INTO THE DESIGN OF BaFeO₃-BASED PEROVSKITE CATHODES FOR SOLID OXIDE FUEL CELLS

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Abstract

BaFeO₃-based perovskite materials have attracted considerable attention due to their excellent triple-conducting properties. However, their susceptibility to phase transitions at high temperatures limits their reliability in solid oxide fuel cells (SOFCs). Doping has been demonstrated as an effective strategy to stabilize the BaFeO₃ structure and enhance its triple-conducting performance. In this work, we focus on BaFeO₃-based perovskites by integrating machine learning (ML) with first-principles calculations. Three ML models were developed and trained based on different dopant elements, and molecular dynamics simulations were employed to evaluate the reliability of the materials at larger scales. The ML approach effectively reduced computational costs, achieving a balance between the accuracy of first-principles methods and the efficiency of molecular dynamics. The results reveal that Bi and Ce doping can significantly decrease the thermal expansion coefficient of BaFeO₃, which is reduced by 56.80% and 31.37% at 1100 K compared to the undoped structure, respectively. Mechanical tests at different temperatures further indicate that the elastic modulus decreases by 29.17% with Bi doping and by 44.15% with Ce doping relative to room temperature. These findings demonstrate that Bi doping effectively stabilizes the crystal structure, thereby improving the compatibility between the cathode and electrolyte. The underlying mechanisms can be attributed to the larger ionic radius of Bi compared with Fe, which reduces structural distortion, as well as the valence compensation effect introduced by Bi ions, which enhances the stability of Fe ions. This study provides design guidelines and performance predictions for triple-conducting cathode materials in SOFCs.

Keywords: Solid Oxide Fuel Cells; Triple-phase conduction; BaFeO₃-based perovskite; Machine learning

Acknowledgement

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A NOVEL METHOD FOR PREDICTING FATIGUE LIFE OF GH4169 SUPERALLOY WELDED JOINTS BASED ON AI AND PHYSICS OF FAILURE

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Abstract

This study is dedicated to establishing a new fatigue life prediction model for welded joints that comprehensively considers the effect of welding defects and the physical mechanism of fatigue failure. Firstly, an improved fatigue model for welded joints based on damage tolerance concept is proposed, in which fatigue-critical factors such as the geometric characteristics and location of welding defects are fully considered. Secondly, the proposed physical model is incorporated into a popular machine learning approach of support vector regression (SVR) that is suitable for training fatigue test data, such that a physics-guided artificial intelligence (AI) method is established. The developed method was then applied to predict the fatigue life of welded joints of GH4169 nickel-based superalloy under different fatigue testing conditions at high temperatures. The experimental results show that the life prediction accuracy of the proposed physics-integrated SVR method is significantly higher than that of purely physics-based or purely data-driven methods. Moreover, the proposed method also exhibits better prediction capacity and applicability compared with other physics-AI hybrid methods for fatigue assessment of defect-containing welded joints. This is supported by the fatigue mechanism confirmed by fractographic analysis, demonstrating the promising potential of this physics-integrated AI approach in fatigue life prediction.

Keywords: Welded joints; Fatigue life prediction; Machine learning; Support vector regression; Damage tolerance

Acknowledgement

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AI IN METALLOGRAPHY

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Abstract

Integrating AI into various manufacturing and quality control processes is extremely popular these days. Of course, the integration of artificial intelligence into the process can also be a significant step in certain fields of science, such as metallography and the quantitative analysis that is so often used within it. However, this process is not that simple. as it seems at first. Several parameters can be critical in terms of effectiveness. For example, such parameters are the choice of the learning method, as well as the reliability of thousands of already processed image-based information that form the basis of the procedure. Perhaps one of the biggest tasks is collecting and organizing the right amount of processed image information. In my article, I would like to present the complexity of the topic, the learning methods from which we can choose, and the set of information that is essential so that the result is usable and can be integrated the process of the metallography analysis. Furthermore, our current article is representing the results that we are able to present at this stage of our research.

Keywords: AI; AI integration to Metallography; Quantitative image analysis; Measurement; AI development

Acknowledgement

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APPLICATION OF AI IN AGRICULTURAL MACHINERY MAINTENANCE AND DIAGNOSTICS

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Abstract

Ensuring global food security and promoting sustainable agricultural practices require advanced technological solutions, with artificial intelligence (AI) playing a key role. In agriculture, AI involves methods such as machine learning, deep learning, and computer vision, which enable sophisticated data analysis and intelligent machine operation. These technologies support applications including yield forecasting, climate impact assessment, livestock management, as well as the detection of diseases, pests, and weeds. Our research aims to examine previous studies related to the wear of tillage machinery and to explore the potential integration of AI into this field.

This review highlights how AI-based agricultural systems contribute to autonomous machinery control, improved energy efficiency, and the advancement of precision farming. By applying AI, labor and resource demands can be reduced while production efficiency and environmental sustainability are enhanced. Furthermore, this paper seeks to outline approaches for predicting and managing machinery wear in response to the changing requirements of modern agriculture. Overall, the review provides an in-depth perspective on the role of AI in agriculture, emphasizing its potential to drive more efficient, intelligent, and sustainable technological solutions for the future.

Keywords: Artificial intelligence in agricultural machinery; machine learning; deep learning

LSTM PREDICTION OF TEMPERATURE EVOLUTION IN WIRE-ARC ADDITIVE MANUFACTURING

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Abstract

Additive manufacturing (AM) is important for modern industrial manufacturing, enabling the production of complex parts without the need for customized molds and with reduced material waste. However, AM currently has several drawbacks, including significant residual stresses induced by the powerful localized heat source used. An improved understanding of the link between process parameters, the resulting temperature field, and the residual stress distribution is needed to increase the viability of AM for industrial applications. While numerical methods such as the finite element (FE) method can be used to model AM processes, they are often both computationally expensive and time-consuming. Data-driven methods are therefore being explored as faster and more computationally efficient alternatives. Many of these methods fall under the umbrella of machine learning – methods which use algorithms to learn from large amounts of training data.

In this study, we have explored the application of machine learning, specifically long short-term memory (LSTM) networks, to study the temperature evolution during wire-arc AM (WAAM). FE simulations were conducted for WAAM deposition of rectangular bars and a square plate to generate training and validation datasets. The LSTM networks were trained on temperature data from the deposition of the shortest rectangular bar and used to predict temperature evolution in the other simulated cases. Additionally, the predicted temperatures were used as input for structural FE simulations to evaluate residual stress distribution, which were compared with those obtained with fully FE-based temperature data.

Our results show that our LSTM-based models are able to predict the temperature evolution in rectangular bars with lengths up to four times that of the training system with great accuracy, with a low mean absolute percentage error (MAPE). Although the predictions for the square plate show slightly higher error, the MAPE still remains below 1% on average, highlighting the robustness of the proposed approach.

The article considers two cases of welded joint analysis - a bracket for a truck footboard support and a fuel tank bracket, which are characterized by a defect in the structure's warping. In the first case, this leads to harmful contact and damage to the paintwork of the front wing of the vehicle when the cabin rolls over, and in the second case, to non-compliance with the requirements of the design documentation. The ESI Group programs were used for modeling, in particular SYSWELD. As a result of the modeling analysis and comparison with measurements, it was revealed that due to the close location of several welds, temperature fields overlap, which leads to significant deviations in shape.

Keywords: Wire-arc additive manufacturing; LSTM networks; Temperature prediction; Residual stress

LONG-TERM STRUCTURAL CAPACITY ASSESSMENT OF AN INDUSTRIAL STEEL CHIMNEY

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Abstract

This paper presents a comprehensive assessment of the structural condition of a steel double-wall industrial chimney over twenty years of operation. The chimney is self-supporting, 35 m high, and connected to a gas-fired boiler. Continuous exposure to combustion products, which possess both abrasive and corrosive properties, has gradually reduced the thickness of the load-bearing outer wall, affecting the stress distribution and overall structural capacity. Detailed measurements of the outer shell thickness were collected at 200 uniformly distributed points along the height and circumference of the chimney, with a total of 13 measurement campaigns conducted between 2005 and 2025. These data allow for a precise quantification of material loss and mass reduction over time.

Based on the measured thickness and mass changes, the structural performance of the chimney is evaluated using finite element analyses. The reduction in shell thickness is incorporated into numerical models to determine its effect on load-bearing capacity under standard design load cases, as well as on natural frequencies and dynamic response. This approach provides insight into how long-term material degradation impacts both static and dynamic behavior of the structure.

By integrating long-term measurements with numerical modeling, the study offers a detailed understanding of structural degradation and its consequences. The results support the development of informed maintenance strategies and enable accurate safety assessments for industrial chimneys subjected to extended service life. This methodology demonstrates the value of combining comprehensive measurement campaigns with finite element analysis to ensure reliable and safe operation of industrial structures over decades.

Keywords: industrial steel chimney; long-term degradation; finite element analysis; structural capacity assessment

Acknowledgement

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3D DEEP-LEARNING IMAGE ENHANCEMENT FOR DEFECT CHARACTERIZATION IN XCT OF CARBON FIBER COMPOSITES PARTS

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Abstract

X-Ray micro-computed tomography (XCT) is essential for non-destructive evaluation of carbon fiber composite (CFC) components in aerospace, such as turbine blade. However, achieving high-resolution (HR) scans sufficient for detailed micro-defect analysis can be time-consuming and resource-intensive or even impossible due physical limitation of lab-scale XCT systems. Super-resolution (SR) techniques offer a promising way to enhance image quality from lower-resolution (LR) acquisitions.

Most of current SR methodologies are predominantly designed for 2D images and demonstrate suboptimal performance when directly applied to volumetric XCT data. Their inability to reconstruct complex 3D structural features and through-plane information limits their utility for XCT applications.

This study collects and utilizes XCT datasets of a CFC turbine blade, acquired with voxel resolutions with HR (28 microns per pixel) and LR (72 microns per pixel). We investigate the application of a 3D Cycle-Consistent Generative Adversarial Network with Enhanced Super-Resolution (3D Cycle-ESRGAN) architecture [1]. This approach aims to learn a mapping from low-resolution to high-resolution 3D volumes, enhancing feature definition and structural integrity crucial for defect characterization. Preliminary SR results (Figure 1) demonstrate perceptible improvements in effective resolution and visual clarity of the XCT volumes. Reconstructed images exhibit sharper delineation of fiber bundles, matrix regions, and manufacturing defects (e.g., porosity, delamination) compared to the original low-resolution data and interpolated upsampling.

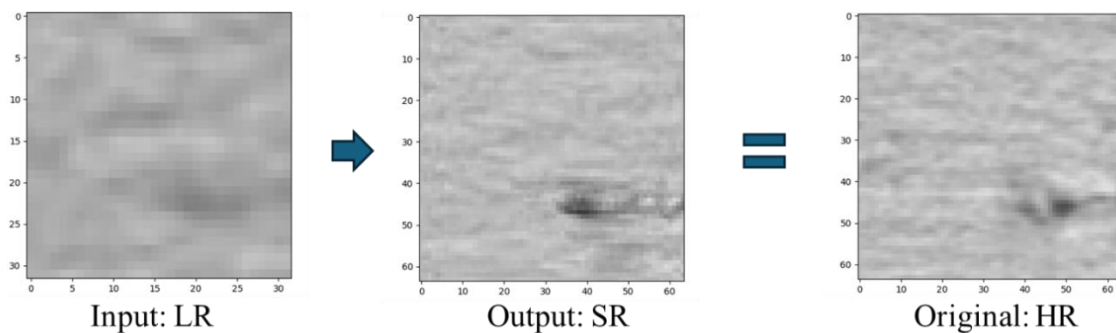


Figure 1. Super-resolution reconstruction of a CT image a pore in CFC component

To further enhance SR performance, particularly in capturing long-range dependencies and complex global features within the 3D CFC structure, we plan to explore transformer-based architectures. These models, with their attention mechanisms, hold potential for superior contextual understanding and reconstruction fidelity in volumetric SR tasks.

The application of 3D Cycle-ESRGAN shows considerable promise for super-resolving industrial XCT data of CFC turbine components, overcoming limitations of existing 2D-centric methods. Future integration of

transformer models is anticipated to push the boundaries of achievable resolution and detail, ultimately improving the reliability and efficiency of non-destructive evaluation for critical aerospace structures.

Keywords: super-resolution; composite materials; computed tomography; deep learning

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INTERPRETABLE MACHINE LEARNING FOR PREDICTING COMPLEX PROPERTIES OF CERAMIC MATERIALS: A BIG DATA APPROACH

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Abstract

As ceramic production evolves toward digital transformation, the role of data-driven modeling becomes increasingly vital. This work explores how advanced machine learning (ML) techniques can extract actionable insights from large, multi-dimensional datasets describing the chemical, mineralogical, and granulometric characteristics of ceramic raw materials. Two key production phases—shaping/drying and firing—are modeled to predict critical quality parameters such as plasticity, drying loss, water absorption, and bending strength. Ensemble models, particularly Gradient Boosting and CatBoost, delivered superior performance ($R^2 > 0.98$), while SHAP analysis enabled interpretability of feature contributions. By revealing complex, non-linear relationships and material thresholds, these models support real-time process tuning, smarter material selection, and enhanced sustainability. The study showcases how big data and explainable AI (XAI) techniques can drive innovation in materials science and industrial process control.

Keywords: big data, machine learning; explainable AI; ceramics; predictive analytics; SHAP, smart manufacturing

MACHINE LEARNING METHODS FOR PREDICTION OF WÖHLER CURVES OF STEEL CK 35

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Abstract

The fatigue behavior of materials is often analyzed using S-N (Wöhler) curves that express the relationship between a stress level and the number of cycles to failure. This study is dealing with predictions of S-N behavior of quenched and tempered steel Ck 35 (DIN/EN) for different groups of specimens using three machine learning models: Support Vector Machine (SVM), Linear Regression (LR), and Gaussian Process Regression (GPR), implemented in the software package MATLAB. Using a material identifier extracted from sample codes, the dataset is partitioned into distinct groups. Available fatigue data for each group is alternately split into training and test sets. To better fit the expected S-N curve relationship, both the stress (S) and cycle count (N) values are converted to a logarithmic scale. Each model is trained separately to predict fatigue life based on applied stress. Each model's predictive performance was evaluated using mean absolute percentage error. SVM and GPR models trained all groups and performed better than classical linear regression, particularly in nonlinear groups. Each group's predicted and experimental S-N curves were compared to assess accuracy. This approach indicates that there is a possibility of reducing the scope of experimental testing through the application of intelligent algorithms.

Keywords: S-N curves; Machine learning; Support Vector Machine; Linear Regression; Gaussian Process Regression; Predictions

PRELIMINARY STUDY ON THE INVERSE DESIGN OF HIERARCHICAL SPINODOID MECHANICAL METAMATERIALS

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Abstract

Spinodoid mechanical metamaterial has received increasing interest in the last decade, thanks to its tunable stochastic and defect-insensitive [1-2] design. However, the mechanical response of spinodoid mechanical metamaterials is strongly correlated with generated stochastic designs, which might offer very poor mechanical performance and very large variation of mechanical properties (e.g., stiffness and anisotropy), thereby limiting wider applications in industry. To tackle this design challenge, we exploited the concept of hierarchical design, which has been proven a successful solution that Nature adopt to generate structures with tunable enhanced mechanical properties.. Moreover, to effectively explore the huge design space still offered by hierarchical spinodoid mechanical metamaterials, we exploited an artificial intelligence (AI) based approach.

In this work, the hierarchical design principle of spinodoid mechanical metamaterials has been investigated first, with a following 2D and 3D a geometrical characterization of . After that, Finite element (FE) simulations have been conducted with the commercial FE software Abaqus, to obtain the effective stiffness of designed hierarchical spinodoid mechanical metamaterials. The results of FE simulations have formed the database for the AI-based approach. A Graph neural network, which offers great potential in the design of materials, has been constructed as the predictor of effective stiffness of the investigated hierarchical spinodoid mechanical metamaterials. Finally, the GNN-based predictor has become the surrogate model in the inverse design algorithm, to optimize the effective stiffness of hierarchical spinodoid mechanical metamaterials. In conclusion, this work aims at creating a solid foundation for applying hierarchical spinodoid mechanical metamaterials for wider industrial applications in future.

Keywords: Spinodoid mechanical metamaterials; hierachical design; GNN; iinverse design

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PRELIMINARY STUDY ON THE PREDICTION OF MECHANICAL BEHAVIOR OF HIERARCHICAL VORONOI-LIKE MECHANICAL METAMATERIALS VIA GNN-BASED APPROACH

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Abstract

Natural cellular materials—e.g., bone, wood, and honeycomb—are known for their extraordinary mechanical performance, such as strength-to-weight and damage tolerance. One of the common geometrical features of these natural cellular materials is their Voronoi-like structure, which has been demonstrated as a critical mechanism to improve mechanical performance by studies in recent decades. Inspired by these interesting structures, scientists and engineers have developed Voronoi-like mechanical metamaterials with tunable mechanical properties for various industrial applications [1]. However, most studies focus on designing fully random or fully ordered Voronoi-like structures, which are not common in Nature. Moreover, natural materials also show hierarchy in Voronoi-like designs. Therefore, to fill this knowledge gap and develop tunable architectures, we elaborated an algorithm to control the finite randomness of Voronoi-like structures and achieve associated hierarchical design. Then, we connected these architectures to finite element (FE) simulations that were performed with the commercial FE software Abaqus to obtain the effective stiffness of the designed Voronoi-like mechanical metamaterials. After that, to understand the contributions of finite randomness and hierarchy, we exploited a data-driven approach, which recently demonstrated strong potential in mechanics-based design, by using FE results as training database. Graph neural network (GNN) [2] which is particularly well-suited to study complex geometric features, was adopted to predict effective stiffness and to understand mechanical contributions from finite randomness and hierarchy. The success of this research has deepened our understanding of hierarchical finite random Voronoi-like mechanical metamaterials, thereby paving the way for their broader adoption in structural, biomedical, and aerospace applications.

Keywords: Voronoi structure; hierarchical design; GNN; finite randomness; FEA

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COMPARATIVE ANALYSIS OF THE ACCURACY OF NEURAL NETWORK AND ANALYTICAL METHODS IN MODELLING FATIGUE FRACTURE OF TITANIUM ALLOY

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Abstract

The problem of fatigue failure of structural materials is extremely relevant in the conditions of increased attention to the reliability and safety of critical structural elements in mechanical engineering, aviation, and energy industries. In particular, classical analytical models provide acceptable accuracy in the middle range of the amplitude of the stress intensity factor ΔK , but demonstrate limitations in describing the boundary regions of the crack growth curve. Therefore, to solve the problems of fracture mechanics, it is advisable to use neural networks to model fatigue processes.

In this paper, the fatigue crack growth rate is modeled by neural network and compared with analytical models, namely, Paris' law and polynomial log regressions of the second to fifth degree. To assess the accuracy of the modeling, the determination coefficient R^2 , mean absolute error (MAE) and mean absolute percentage error (MAPE) were used to assess the accuracy of the modeling. The results showed that both approaches, in particular, the classical analytical models and the neural network, provide the high accuracy of approximation of the experimental data. At the same time, the neural network demonstrated an advantage in the region of high values of ΔK , where a nonlinear acceleration of crack growth is observed, reaching a coefficient of determination R^2 equal to 0.9994.

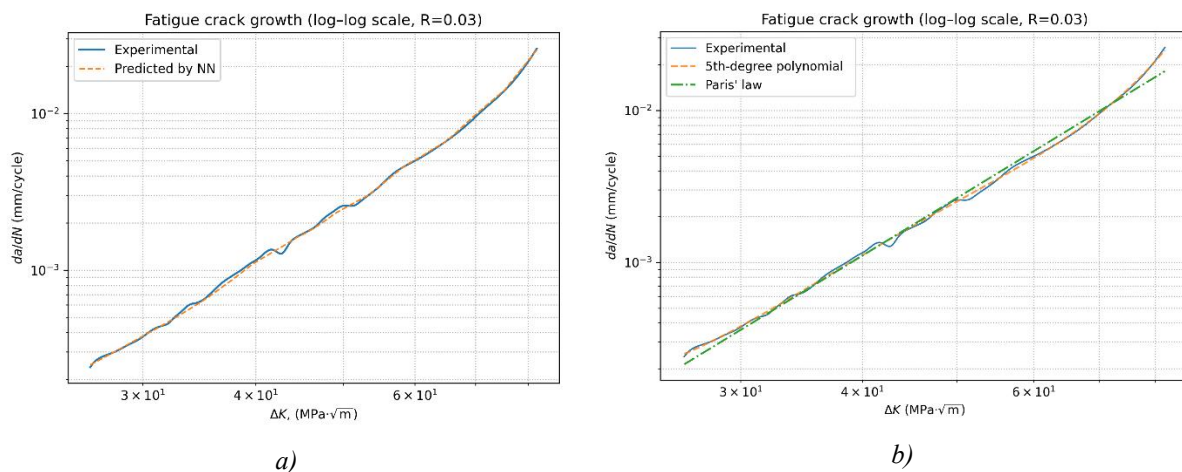


Figure 1. The predicted and experimental dependences of the FCG rate on the ΔK for $R = 0.03$ by method of neural networks (a) and analytical methods (b)

The presented approach confirms the effectiveness of applying machine learning methods, in particular, neural networks, in the problems of fracture mechanics and fatigue analysis.

Keywords: fatigue failure; machine learning; neural network; analytical models

PREDICTION OF SMA HYSTERESIS BEHAVIOUR BY ENSEMBLE STACKING MACHINE LEARNING

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Abstract

Shape memory alloys (SMAs) are essential in many industries due to their unique properties, such as shape memory and superelasticity. Superelasticity manifests itself in the ability of a material to undergo significant deformation and fully restore its original shape after the load is removed without residual deformation. Hysteresis in SMA is a characteristic that describes the behavior of a material during phase transitions between the martensitic and austenitic phases. The area of the hysteresis loop on the stress-strain (σ - ϵ) graph is numerically equal to the dissipated energy. Predicting the nonlinear hysteresis behavior under multiple loads is critical for designing durable products, but traditional models often do not adequately reflect the actual experimental data.

In this work, an ensemble stacking machine learning model for predicting hysteresis loops was developed and tested. Experimental data of 150 load-unload cycles of NiTi alloy were used to train and test the model. The MAE, MSE, R2, and MAPE metrics were used to evaluate the quality of the model. Figure 1 shows the experimental hysteresis loop of the 300th load-unload cycle and the predicted hysteresis loop using the stacking machine learning model.

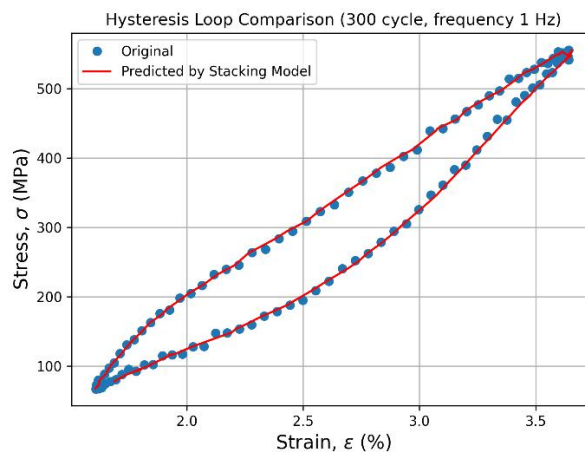


Figure 1. Experimental hysteresis loop and predicted by the stacking machine learning model

The obtained results confirm the effectiveness of the ensemble stacking model in predicting the nonlinear hysteresis behavior of shape memory alloys.

Keywords: SMA; Machine learning; hysteresis; stacking model

NUMERICAL AND EXPERIMENTAL STUDY ON FLOW LOSS REDUCTION EFFECT OF MICRO-TEXTURED SURFACE

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Abstract

The application of advanced flow control methods for the aerodynamic design of civil aircraft is of great significance to enhance the aerodynamic efficiency and flight profitability. With the development of the interdisciplinary approach between materials science and aerodynamics, the design of flow control for aerodynamic configurations using micro/nanoscale surface structures has attracted a lot of attention. Due to the huge difference in scale between microstructures and macroscopic aircraft, both numerical and experimental studies of aerodynamic configurations covering micro/nano surface structures are limited, and the flow control mechanisms and effects need to be further investigated. In this paper, an ANN-Based boundary strategy is proposed to balance the accuracy and efficiency. Lattice Boltzmann Method (LBM) is utilized to extract the near-wall high-fidelity CFD data of micro/nanoflow and the available microscopic data is used to train the surrogate boundary model by Generalized Regression Neural Network (GRNN). The modified boundary conditions obtained by ANN-Based model replacing the real complex and fine micro/nano structure are applied on the smooth configuration to perform macroscopic simulations. The purpose of this paper is to develop an accurate and efficient aerodynamic simulation strategy for the macroscopic configuration with micro/nano surface structures, and to verify its effectiveness in combination with wind tunnel tests.

Keywords: flow control; micro-textured surface; boundary model; aerodynamic performance

BAYESIAN DEEP LEARNING FRAMEWORK FOR DUAL UNCERTAINTY QUANTIFICATION IN CORROSION FATIGUE LIFE PREDICTION

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Abstract

Corrosion fatigue of steel wire is a critical issue affecting the durability and safety of infrastructure such as bridges and concrete structures. The fatigue life of corroded steel is primarily governed by service loading conditions and corrosion severity. However, most existing prediction methods are deterministic, estimating only the mean or median fatigue life while neglecting model error (epistemic uncertainty) and the inherent variability in fatigue life (aleatoric uncertainty). Such simplifications result in limited prediction accuracy and reliability. To address these challenges, this study develops a Bayesian deep learning framework based on a probabilistic neural network. The proposed model takes loading and corrosion states as inputs and outputs the parameters of the log-fatigue life distribution, enabling joint modeling of epistemic and aleatoric uncertainties. The model was validated on a dataset of 218 steel wire corrosion fatigue life measurements, achieving R^2 of 0.93 and RMSE of 0.14 on the test set. The 95% confidence interval coverage rate reaches 95.41%, confirming strong predictive accuracy, reliable uncertainty quantification, and good potential for supporting the design, maintenance, and life-cycle management of reinforced concrete and bridge structures.

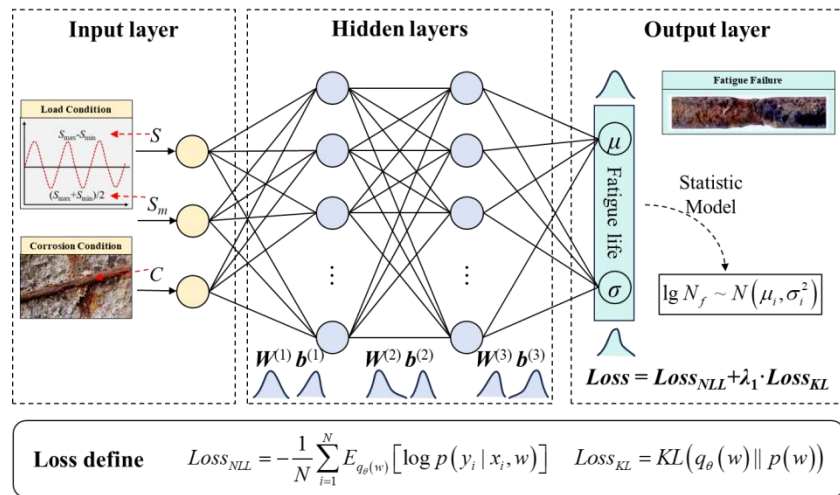


Figure 1. Bayesian Deep Learning Framework for Corrosion Fatigue Prediction.

Keywords: corrosion fatigue; dual uncertainty; Bayesian neural network; probabilistic prediction; steel wire

Acknowledgement

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ENHANCING STRUCTURAL INTEGRITY OF SLA 3D-PRINTED LATTICES VIA AI-BASED MECHANICAL RESPONSE OPTIMIZATION

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Abstract

This study explores the additive manufacturing of lattice structures via stereolithography (SLA) 3D printing, focusing on the influence of layer thickness and cell scale on mechanical performance. Five lattice architectures, Diamond, Fluorite, Body-Centered Cubic (BCC), Face-Centered Cubic (FCC), and Octet, were fabricated with systematically varied parameters. Compressive tests were conducted both parallel and orthogonal to the printing direction to assess anisotropic mechanical behavior.

To enable predictive modeling, artificial intelligence (AI) frameworks based on recurrent neural networks (RNNs) and multilayer perceptrons (MLPs) were developed to estimate the mechanical properties of the lattices using input variables such as layer thickness, lattice type, cell scale, and testing orientation. A genetic algorithm (GA) was subsequently implemented, leveraging the trained AI models as a virtual environment to identify optimal combinations of lattice parameters that achieve user-defined mechanical property targets.

By integrating experimental characterization, AI-driven prediction, and evolutionary optimization, this work establishes a comprehensive framework for the design and customization of 3D-printed lattice materials, advancing the development of structures with tailored mechanical properties.

Keywords: AI-Based Design Optimization; Lattice Structures; Additive Manufacturing

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- W. Gao, M. Qin, W. Song, G. Cheng, H. Hu - *Numerical Simulation of Hydrogen Embrittlement Coupling in L245 Steel Pipelines*

FRACTURE SIMULATION AND STRUCTURAL INTEGRITY OF 3D-PRINTED TOE IMMOBILIZERS FABRICATED VIA ADDITIVE MANUFACTURING

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Abstract

This study presents an advanced mechanical analysis of additively manufactured toe immobilizers using FEM simulations to evaluate structural integrity and fracture resistance. The designs aim to aid orthopedic recovery of the fifth toe and incorporate two internal geometries, trapezoidal ribs and Voronoi lattices, optimized for light weight and anatomical conformity. The parametric CAD models were developed and analyzed using Autodesk Fusion 360, with boundary conditions and loading regimes approximating physiological toe pressure. Material behavior was defined as linear-elastic using ABS-like plastic properties and von Mises stress fields were calculated to evaluate critical stress concentrations and predict structural performance. A design matrix of 18 variants, differing in rib thickness and number, was analyzed for safety factors and stress reinforcement zones. Trapezoidal designs outperformed the Voronoi configurations in terms of stress homogenization and structural safety, particularly at the rib-plate connections. The study highlights both the capabilities and limitations of linear static FEM and emphasizes that while simulation provides important insights for early design validation, factors such as fatigue, viscoelastic behavior and real interface interactions need to be verified experimentally. The results support FEM as a robust tool for the design of lightweight, fracture-resistant biomedical orthoses. This approach provides a framework for the future design and evaluation of additively manufactured immobilization systems and ultimately contributes to improved clinical outcomes in orthopedic rehabilitation.

Keywords: Additive manufacturing; finite element method (FEM); toe immobilizer; Von Mises stress; orthopedic rehabilitation

Acknowledgement

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RAPID PREDICTION OF HIGH-CYCLE FATIGUE PROPERTIES OF HIGH-ENTROPY ALLOYS BASED ON SLIP IRREVERSIBILITY LOCALIZATION

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Abstract

This paper is devoted to exploring a rapid evaluation method for fatigue properties of multi-component high-entropy alloys (HEAs) based on a new fatigue indicator parameter (FIP) of slip irreversibility localization. The studied material is a type of Al_xCoCrFeNi_y HEA with variable Al and Ni contents, which makes its fatigue properties variable over a considerable range and difficult to predict. The proposed FIP takes into account in a comprehensive manner the irreversibility and localization of slip, the two most critical factors promoting fatigue crack nucleation at the mesoscopic scale. The evaluation can be efficiently achieved by molecular dynamics simulations of dislocation behavior at the atomic scale under cyclic loading. The simulation results show that different element ratios in the studied HEAs can significantly affect the features of irreversible localization of slip and thus the nucleation conditions of fatigue cracks. These fatigue-critical characteristics can be sensitively reflected in the proposed FIP and can be determined quantitatively and effectively in the early stages of fatigue. The developed method is applied to predict the fatigue strength of HEAs with different element ratio combinations, and the predicted results are in good agreement with the experimental data.

Keywords: Slip irreversibility; Slip localization; Fatigue properties; High-entropy alloys; Molecular dynamics

Acknowledgement

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RISK-BASED STRUCTURAL INTEGRITY OF A FEED GAS ADSORBER WITH AN EXTERNAL SURFACE CRACK

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Abstract

A fitness-for-service assessment is presented for a Feed Gas Adsorber 16A01A, manufactured from SA-350 LF2 and operating at an internal pressure of 11.005 MPa and a temperature of 270°C. During inspection, an external surface-breaking crack was detected on the cylindrical shell. The study follows two complementary routes: (i) re-qualification per ASME BPVC Section VIII, Division 2, Class 2, and (ii) corroborating checks per GOST 34233.2-2017. The minimum required thickness of the cylindrical shell is determined and compared with the measured wall after flaw removal by controlled grinding. Temperature-dependent mechanical and fracture properties of SA-350 LF2 are compiled for analysis.

Local stresses in the indication zone are quantified using a detailed finite element model of the shell. Structural integrity is then evaluated by two approaches. The “modern,” risk-based route applies a Failure Assessment Diagram (FAD) to the as-found defect and to the post-grind geometry, including sensitivity to flaw sizing, residual stress, and toughness. The “classical” fracture-mechanics route determines stress-intensity factors and compares them with fracture toughness at service temperature. Results indicate that complete removal of the surface crack by shallow grinding restores sufficient wall thickness and keeps assessment points within the safe FAD region, with local stresses meeting allowable limits. The workflow provides a practical methodology for continued safe operation of pressurized vessels with external surface cracks, integrating code thickness checks, risk-based integrity assessment, and FEM substantiation.

Keywords: structural integrity; crack resistance; crack driving force; feed gas adsorber; pressure vessel

FATIGUE CRACK GROWTH IN HIP IMPLANTS UNDER COMBINED LOAD CONDITIONS

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Abstract

This paper provides a comprehensive numerical investigation into the mechanical behavior of partial orthopedic Ti-6Al-4V implants exhibiting crack-like defects, with particular emphasis on the application of the finite element method (FEM). In the numerical investigations presented, partial hip prostheses that failed during service were selected for analysis. Crack locations were defined based on the actual fracture sites observed in clinical cases and further experimental analysis determined the critical locations within the implant. Two failure scenarios were examined under realistic loading conditions, fracture at the upper or lower opening, and corresponding numerical models were developed to reflect these distinct loading cases. Based on these critical locations, numerical simulations using finite element method (SMART) were performed. The goal was to compare the results for fatigue crack growth during combined load, for two different crack locations in partial hip implants. The findings revealed substantial variability in fatigue life across different loading conditions, thereby underscoring the necessity of individualized analysis, given the pronounced influence of patient-specific activity profiles on implant stress responses. Obtained results had shown that one crack location had a significantly longer fatigue life. Question remains about how real models failed with such a crack, since the other crack location is much more critical, and more likely to occur due to higher tensile stresses in the region of its initiation. In conclusion, the utilization of advanced numerical techniques facilitated preliminary assessments of implant behavior under cyclic fatigue loading across multiple scenarios. These insights offer a valuable predictive framework for assessing the likelihood of failure in Ti-6Al-4V alloy implants subjected to variable loading regimes.

Keywords: Hip implants; finite element method; fatigue crack growth; combined load

STUDY OF HYDROGEN-INDUCED CRACKING IN X65 PIPELINE STEEL BY USING THE H-CGM+ FRAMEWORK

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Abstract

Hydrogen-induced cracking of X65 pipeline steel under in-situ electrochemical charging is examined using the predictive H-CGM+ framework. H-CGM+ is a mechanism-informed, void-based model capable of capturing diverse hydrogen embrittlement phenomena, spanning hydrogen-suppressed ductile fracture and hydrogen-enhanced decohesion (quasi-cleavage). These fracture modes are directly linked to hydrogen-enhanced localized plasticity and hydrogen-enhanced decohesion mechanisms, respectively. To replicate crack initiation, propagation, and arrest, a three-stage testing protocol, rising displacement, stepwise constant load, and sustained load, was numerically simulated. The model accounts for hydrogen uptake coupled with mechanical deformation, incorporating stress-assisted diffusion and plastic-strain-controlled trapping. Predictions reproduce experimental crack evolution with high fidelity, showing that crack arrest under sustained loading arises from secondary branching within the hydrogen-affected zone. A critical failure criterion, combining local hydrogen concentration and accumulated plastic strain, is established. This reveals a fundamental shift in failure initiation sites: from the specimen center in air to the notch surface under hydrogen charging. These insights provide a mechanistic basis for assessing hydrogen pipeline integrity and guiding safe operation under long-term loading conditions.

Keywords: Hydrogen embrittlement; Pipeline steel; Fracture toughness; Complete Gurson model

Acknowledgement

The authors thank to the support provided by Research Council of Norway through the HyLINE II (344377) project.

DAMAGE INITIATION AND EVOLUTION OF EXPLOSIVE CHARGE WHEN A PROJECTILE PERFORATES MULTILAYERED TARGETS

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Abstract

When a projectile perforates multilayered targets, the accompanied high impulsive overload will affect the behavior and thus the performance of explosive charge. We build up a strain-rate-dependent cohesive zone model to investigate the damage initiation and evolution of charge under these overloads. In the model, we calibrate the critical normal separation to describe the macrodamage evolution of charge. We find that the normal separation at the interior of charge is smaller than that in the edge and that the angle between the macrodamage area and the axial direction of projectile decreases with the obliquity of targets. Both the maximum normal separation and the macrodamage proportion during oblique penetration are revealed to be larger than those during normal penetration. As the projectile velocity increases, both the maximum normal separation and the total macrodamage proportion get larger, and severe macrodamage area becomes closer to the tail. As the targets spacing increases, the severe macrodamage area becomes farther from the tail.

Keywords: Explosive charge; damage; cohesive zone model; strain rate; macrodamage area

A COHESIVE ZONE MODEL FOR PREDICTING HYDROGEN-ASSISTED FATIGUE CRACK INITIATION IN SUBSEA PIPELINES WITH INITIAL DEFECTS

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Abstract

The synergistic effects of initial defects and hydrogen embrittlement on hydrogen-assisted fatigue crack initiation (HAFCI) in subsea pipelines is investigated. A model for predicting HAFCI life, in which a four-stage elastoplastic constitutive model considering hydrogen-induced dislocation effects with a cyclic cohesive zone model are integrated, is employed for the simulation. Finite element (FE) models of pipelines with initial defects of varying geometries are established. By defining fatigue crack initiation as the occurrence of successively failed elements, the combined effects of single defect size and multi-defect interactions on HAFCI life of pipeline are discussed. Results show that crack initiation is accelerated significantly by the coupling effects of hydrogen embrittlement and initial defects. Compared to defect-free models, a substantial decrease in hydrogen-assisted fatigue initiation life is induced by the presence of initial defects, and these effects are found to be more pronounced with the increase of defect sizes. Furthermore, a fatigue damage accumulation effects between multiple defects are observed when their spacing is below a critical value, which further exacerbates hydrogen-assisted fatigue failure. These findings provide a crucial theoretical basis for the hydrogen-assisted fatigue life assessment and structural integrity management of pipelines containing defects.

Keywords: Hydrogen embrittlement; hydrogen-assisted fatigue crack initiation; cyclic cohesive zone model; subsea pipeline; initial defects

Acknowledgement

This research was supported by the National Natural Science Foundation of China (Grant No. 52311530091). The financial supports are greatly appreciated.

DETERMINATION OF THE LIFETIME BY THE FINITE ELEMENT METHOD OF ROUND SMOOTH SPECIMEN EXPOSED TO LOW CYCLIC FATIGUE

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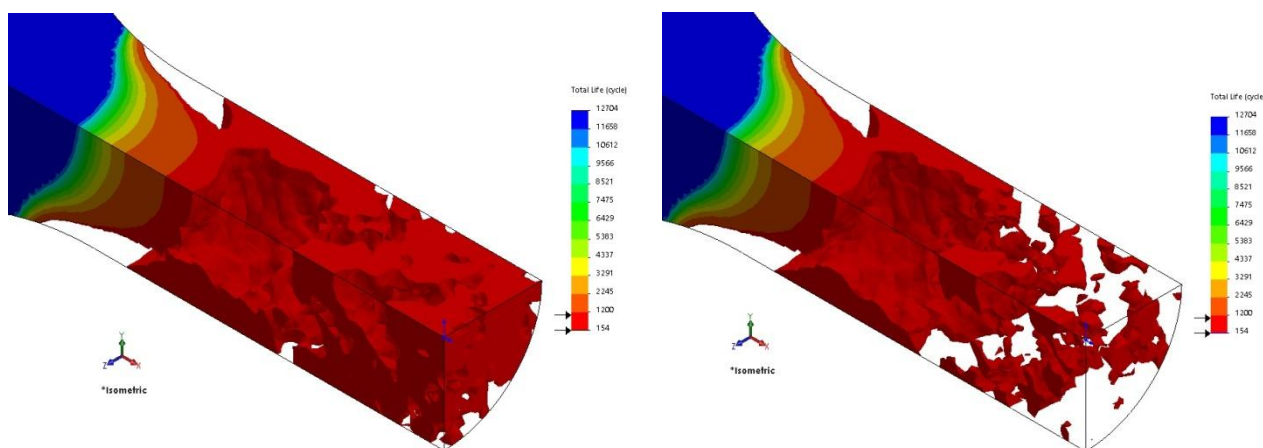
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Abstract

In the paper, based on the results of experimental research on the behavior of samples made of high-strength low-alloy steel (HSLA), Nionical 70 (NN-70), in the form of a round smooth specimen (RSS) under conditions of low cyclic fatigue (LCF), a computational stress analysis was performed using the finite element method (FEM), in the Cosmos module of the SolidWorks program.

Based on the analysis of the results of the stress-strain state and determination of the service life via the service life isolines, Fig. 1, for a certain load cycle that affects the entire RSS ligament for a certain load in a wide range of LCF loads and comparison with the results of experimental tests, conclusions were drawn that justify the efforts to solve the service life assessment of a machine element loaded with low-cycle fatigue numerically.

The results of experimental tests and test simulations (FEM, LCF in the SolidWorks program) also provided us with important data on understanding the LCF behavior of HSLA steel, NN-70.



5 cycles before failure, $N_f=1060$, Isovolum reading

Failure cycle, $N_f=1065$, Isovolum reading

Figure 1. Determination of the failure cycle of OGE made of NN-70 steel, using the finite element method, for a load of 27 kN

Keywords: low cycle fatigue (LCF); service life; finite element method (FEM)

Acknowledgement

This research is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-136/2025-03/200012).

PARAMETER AND TOPOLOGY OPTIMIZATION FOR LIGHTWEIGHT AND RELIABILITY ENHANCEMENT OF A CYLINDER HEAD

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Abstract

The cylinder head of high-power-density diesel engine is one of the most critical components with complex structure, which suffer combined high cycle mechanical and low cycle thermal loads. Nowadays, the requirements for reliability and lightweight design of cylinder head are continuously increasing. Therefore, parameter and topology optimization for a cylinder head was conducted under constrained thermal-mechanical loads. Firstly, 72 variable parameters were extracted and a parameterized geometric model of the cylinder head was established. Subsequently, heat transfer and thermal-mechanical stress calculations were performed to obtain the temperature and stress distributions. Using the parameterized geometric model, simulation model, and Latin Hypercube Sampling, parameter optimization was conducted with the objective of mass reduction and subject to stress and displacement constraints. A total of 5727 calculation sets were conducted during the optimization, with a simulation pass rate of 91.4%, and the parameters that highly affect the mass and thermal mechanical load were obtained. The results show that the three main parameters affecting the thermal-mechanical stress are the dimensions of the convex platform at the top of the water chamber, width and height of the force wall. After parameter optimization, topology optimization was conducted using Tosca Structure software to improve structural smoothness and castability. Finally, the combined optimization achieved an 11.9% reduction in mass, with the maximum thermal mechanical stress and displacement remained approximately constant.

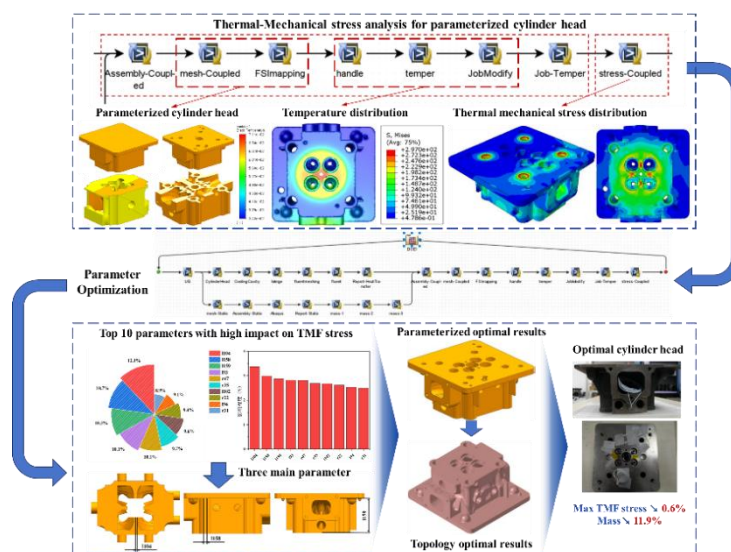


Figure 1. Graphical Abstract

Keywords: Draw hook; Failures; Safety; Rolling stock; Rail Vehicles

A MECHANISTIC VOID-BASED FRAMEWORK FOR PREDICTING HYDROGEN EMBRITTLEMENT: DOES CONSTRAINT STILL GOVERN FRACTURE TOUGHNESS UNDER HYDROGEN?

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Abstract

The structural integrity of hydrogen transport and storage infrastructure depends critically on our ability to predict fracture toughness under hydrogen exposure. While high crack-tip constraint is known to result in low fracture toughness in air, the applicability of this principle in hydrogen-charged environments remains uncertain due to the complex interplay between mechanical fields, hydrogen transport, and embrittlement mechanisms. To address this open question, we develop H-CGM+, a mechanism-informed, void-based predictive framework that captures hydrogen effects by integrating fundamental mechanisms—hydrogen-enhanced localized plasticity (HELP), hydrogen-enhanced strain-induced vacancy formation (HESIV), and hydrogen-enhanced decohesion (HEDE) alongside multiple plastic strain–hydrogen trapping relationships. In particular, this framework allows the competition between hydrogen-suppressed ductile fracture and hydrogen-enhanced brittle fracture within a unified formulation. By systematically varying crack-tip constraint, hydrogen concentration, and microstructural sensitivity, we demonstrate that, within the current mechanistic understanding, higher constraint continues to correlate with lower fracture toughness, mirroring behavior in air. However, this result depends on the prevailing set of recognized hydrogen embrittlement (HE) mechanisms; if alternative or competing mechanisms emerge, this foundational principle may not hold—potentially reversing the role of constraint and altering the integrity assessment paradigm. These findings highlight both the predictive power and current limitations of H-CGM+ as a modeling platform. It provides a robust and adaptable tool for evaluating hydrogen-assisted fracture, while also emphasizing the urgent need to validate key assumptions through focused experimental and theoretical efforts.

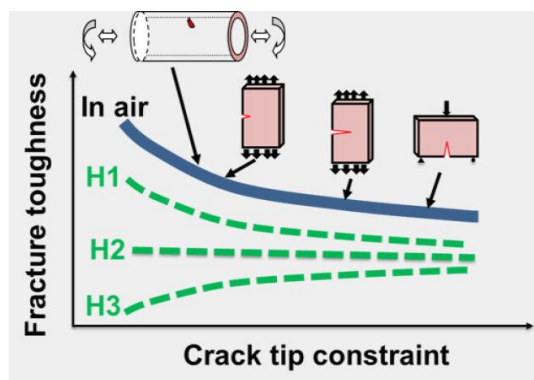


Figure 1. Example

Keywords: Structural integrity; Boiler; Superheater; Microstructure; Welding

FATIGUE CRACK EVOLUTION OF THIN-WALLED PIPE BENDS BASED ON PHASE-FIELD THEORY

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Abstract

Pipe bends are commonly used components in piping systems, where the fatigue fracture under cyclic loading is the predominant failure mode. Accordingly, identifying crack locations and developing preventive measures against fracture failures have become critical technology challenges. To investigate the fatigue crack behaviour of thin-walled pipe bends subjected to cyclic loading, this study derives a fatigue fracture phase-field model for elastoplastic solids. The proposed model incorporates the coupled mechanisms of elastoplastic deformation and phase-field fracture, extending the framework of brittle fracture phase-field theory. By using this model, simulations are performed to examine the fatigue fracture behaviour of pipe bend structures. Besides, the effects of cyclic loadings on crack propagation and material damage in pipe bends are systematically analysed. Results demonstrate that the proposed fatigue fracture phase-field model accurately predicts crack propagation patterns. The outcomes provide a robust theoretical foundation and practical guidance for predicting crack locations and implementing protective measures in engineering applications.

Keywords: Fracture phase-field modelling; Fatigue failure; Thin-walled pipe bends; Crack evolution

Acknowledgement

The authors are grateful for the supports provided by the National Natural Science Foundation of China (52375145), the China Postdoctoral Science Foundation (2023TQ0119, 2024M760909 and GZC20240467), the Shanghai Pujiang Program (No. 24PJD026), and the Natural Science Foundation of Shanghai (25ZR1402111).

INVESTIGATION OF MICROSTRUCTURE AND CRACK TIP MECHANICAL FIELDS DURING SCC PROPAGATION IN SA508–309/308L OVERLAY WELDED JOINTS

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Abstract

Stress corrosion cracking (SCC) is a major threat to the structural integrity of dissimilar metal welded joints (DMWJs) in the primary circuits of pressurized water reactors. However, conventional models usually assume abrupt mechanical property transitions at weld interfaces and primarily focus on stationary cracks, thus failing to capture the evolving mechanical fields near the advancing crack tip. To address these challenges, a field-based user subroutine was implemented to achieve a continuous transition of mechanical properties across the weld interface, thereby avoiding abrupt mechanical mismatches. The evolution of crack-tip mechanical fields during crack growth was analyzed using a de-bond submodel, providing detailed insight into the mechanical behavior near the crack tip. Finally, this study further examines the nonlinear evolution of crack-tip stress and strain fields under various overload ratios. The results reveal that the fusion boundary (FB) shows pronounced microstructural and mechanical gradients, with peak hardness of 272.9 HV and yield strength of 703 MPa. This region is highly susceptible to SCC due to intensified stress redistribution and localized plastic mismatch near the crack tip. Stress–strain field analysis confirms that the FB serves as a “hotspot” for crack propagation, with peak von Mises stress reaching 809 MPa and maximum PEEQ of 5.2×10^{-3} , indicating severe local stress and strain concentration. Overloading leads to enhanced plasticity at the crack tip while stress tends to plateau, revealing a characteristic stress–strain decoupling effect. Although overload increases the crack growth driving force for SCC, it may also temporarily suppress crack growth through mechanisms such as crack tip blunting and enhanced crack closure.

Keywords: Dissimilar metal welded joint; mechanical heterogeneity; Crack propagation; Crack tip driving force; Overload

Acknowledgement

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MECHANICAL PERFORMANCE OF NANO-SILICA MODIFIED PERVIOUS CONCRETE: EXPERIMENTAL TESTS AND LDEM SIMULATIONS

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Abstract

This study investigates the mechanical behavior of nano-silica modified pervious concrete (PCNS) through a combined experimental and numerical approach, aiming to clarify the potential benefits of nano-silica additions and validate advanced modeling strategies. The experimental program compares plain pervious concrete (PPC) and PCNS (3% nano-silica by cement weight) by measuring infiltration rate, density, porosity, and mechanical performance under compression, splitting tensile, and four-point bending. Results indicate that nano-silica markedly reduces the infiltration rate due to the filling effect and the formation of a denser surface layer. However, density and porosity remain statistically unchanged, and no significant improvements are observed in compressive, tensile, or flexural strengths. Moreover, the higher compaction effort required for PCNS induces a vertical density gradient, which negatively affects mechanical response.

To complement these findings, numerical simulations are performed using the Lattice Discrete Element Method (LDEM). In this framework, pervious concrete is represented as a three-dimensional lattice of truss elements governed by a trilinear constitutive law, applied here for the first time to simulate quasi-brittle materials. Material heterogeneity is introduced through a Weibull-distributed random field for fracture energy. The model is calibrated using four-point bending data from PPC and validated against compressive and tensile tests. Predictions show close agreement with experiments, with strength errors below 6% and simulated crack paths consistent with observations.

Overall, the study demonstrates that the LDEM is a robust and reliable tool for simulating the mechanical response of pervious concrete. The model accurately captures experimental behavior under different loading conditions, reproduces crack development, and provides valuable insights for the design and optimisation of heterogeneous cement-based composites.

Keywords: Cement-based composite; Lattice Discrete Element Method; nano-silica; pervious concrete

Acknowledgement

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FAILURE ANALYSIS AND INTEGRITY ASSESSMENT OF A CRACKED PIPELINE ELBOW IN AN OIL TRANSPORT SYSTEM

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Abstract

The pipeline used for transporting crude oil from production wells to the central gathering station was subjected to various stresses and damage mechanisms, including naphthenic acid corrosion, microbiologically influenced corrosion and especially erosion and pressure shock waves (fatigue loadings) like the most impact damage mechanisms. These combined effects eventually led to the failure of a pipe elbow installed in 2003, which cracked after 20 years of continual service. This study was analyzed a root cause of the failure and evaluates several remediation strategies, ultimately recommending the complete replacement of the elbow as the most effective solution. Risk-Based Inspection (RBI) assessment indicated a low risk level, while corrosion rate calculations helped characterize the degradation process. Numerical simulations were conducted on the pipe segment with and without the crack to assess its structural integrity under operating conditions. Once the stress analysis was completed, an appropriate failure criterion was applied to evaluate the strength and integrity of the pipe and its components. The results of this research provide valuable insight into long-term degradation mechanisms in pipeline systems operating under complex environmental and operational conditions. The adopted methodology may serve as a reference for similar cases in the oil and gas industry, helping to prevent future failures and improve maintenance strategies.

Keywords: pipeline failure; corrosion; erosion; MIC; naphthenic acid corrosion; FEA; RBI; structural integrity

Acknowledgement

This research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia through contracts Nos. 451-03-136/2025-03/200013, 451-03-136/2025-03/200051

NUMERICAL ANALYSIS OF RESIDUAL STRESSES FORMED IN A THIN PLATE AFTER LSP

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Abstract

Laser shock peening (LSP) technology is an effective way to create residual stresses in the near-surface area of structures made of metals and alloys. Numerical modeling is widely used to deepen knowledge about the processes occurring during LSP of various materials and also to optimize the parameters of LSP. In this work, the verification of a numerical model for the formation of residual stresses after LSP under different processing modes is carried out. The treatment was conducted with round spots with a diameter of 2 mm and 50% overlapping at the following power densities: 6.31, 9.55, 12.74 and 19.1 GW/cm². The shape (rise and decline time) and pressure value corresponding to each of the processing modes under consideration are selected. The results of numerical modeling were compared with the profiles of residual stresses obtained by hole drilling method on 2 mm thick samples produced by the considered modes. The modelling of the laser shock peening treatment does not consider the process of material evaporation from the surface and the formation of high-pressure plasma. The influence of the laser pulse is taken into account by setting a time-dependent mechanical pressure function on the specimen surface. The calculation of the stress-strain state caused by this loading is performed in the finite element formulation in Ansys LS-Dyna. The problem was solved in a three-dimensional formulation taking into account the finite size of the laser spot.

The purpose of this work is to consider how the field of residual stresses in samples changes when their thickness decreases to 1 mm and smaller. Consequently, the parameters of the developed numerical model were used for this aim. Numerical modeling shows that samples with a thickness of 1 mm have a field of compressive residual stresses formed on the treatment surface, but tensile stresses of up to 200 MPa appear on the opposite side. The fields of residual stresses after alternate hardening on both sides and double-sided symmetric LSP were also considered.

Keywords: Laser shock peening; titanium alloy; finite element modeling; residual stress

Acknowledgement

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ESTIMATION OF THE OPERATION RELIABILITY OF COMPRESSOR SUCTION VESSELS IN OIL AND GAS PLANTS

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Abstract

The paper deals with the problems of the suction pressure vessels, which are a constituent part of the compressor for raw gas, and which are in long-term service. Due to an observed discrepancy with the operating pressure on the suction side of the compressor, the suction vessel was inspected on-site, and a crack was observed, which was confirmed by the penetrant tests. The mentioned equipment was dismantled from the compressor and transferred to the workshop for remediation of the circular weld joint. During preparation of the vessel for repair, which was included excavation of the crack, visual inspection, and penetrant test of the damaged weld joint, it was concluded that the crack was deeply propagated in the base metal of the nozzle and that the affected weld joint and nozzle cannot be repaired. Hence, the decision was made to fully remediate the pressure vessel, which included removing the existing reinforced plate and nozzle and installing new elements. One of the goals of this paper is to determine the initialization of the crack. For this purpose, an initial numerical model was made using finite element method. The model was a simplified version of the real vessel geometry. It was subjected to load which corresponded to the working pressure of 55 bar, and the ultimate goal was to obtain the stress distribution in the vessel, in order to verify the location where the crack had initiated. The location of maximum tensile stress in the model had shown good agreement with the actual crack location, thus confirming the validity of the model. Hence, this paper presents a numerical simulation as a comprehensive method for the stress state of mechanical parts and a useful approach in life assessment. Further research will include simulations of fatigue crack growth, based on the model presented here.

Keywords: Pressure Vessels; Compressor; Weld Joint; Numerical Simulation

Acknowledgement

This research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia through contracts Nos. 451-03-136/2025-03/200135, 451-03-136/2025-03/200066, 451-03-136/2025-03/200051.

VIBRATION RESPONSE ANALYSIS OF OFFSHORE ROCKET LAUNCH PLATFORMS SUBJECTED TO WAKE-INDUCED EXCITATIONS

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Abstract

Offshore rocket launches generate high-temperature, high-pressure exhaust jets that exert substantial impact forces on ocean-based launch platforms. Ensuring the structural integrity of these platforms during sea-based missions requires a comprehensive understanding of their dynamic behavior under rocket wake-induced loads. This study presents a numerical simulation approach to predict the structural response of offshore launch platforms subjected to gas jet impacts. The model incorporates various launch angles and accounts for the multiphase nature of rocket exhaust gases using the Realizable $k-\epsilon$ turbulence model.

First, a numerical model is developed to estimate the impact loads generated by rocket exhaust wakes. These loads are subsequently applied as pressure distributions on the platform deck. Transient dynamic analysis is then employed to evaluate the vibration response of the structure under different launch heights and angles. The simulation results reveal that the initial launch height and angle have a significant effect on the platform's dynamic response. Notably, when the launch height ratio $h/d=2$, larger vibration amplitudes are observed at several monitoring points. Furthermore, appropriate adjustment of the launch angle can effectively mitigate the structural vibrations experienced by the platform.



Figure 1. Offshore Rocket Launch Platforms

Keywords: Offshore Launch Platform; Rocket Exhaust Jet Impact; Transient Dynamic Analysis; Aero-Thermal Environment; Vibration Response

Acknowledgement

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COMPUTATIONAL MODEL FOR THE FATIGUE LIFE ESTIMATION OF CYLINDRICAL ROLLER BEARINGS

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Abstract

This study aims to obtain a computational model for the fatigue life estimation of cylindrical roller bearings. For this objective, the maximum contact pressure, equivalent static Von Mises stress, and equivalent dynamic Von Mises stress were calculated. The effect of design parameters such as geometrical parameters, material parameters and loading parameters on the fatigue failure of rolling bearings was simulated. Equivalent dynamic Von Mises stresses were determined by considering both the alternating stress and mean stress. The fatigue life of cylindrical roller bearings was estimated by using Basquin's equation. The results indicate that increasing the roller element radius and length reduces contact pressure and Von Mises stress, leading to an extended fatigue life. Conversely, higher elastic modulus and applied load increase stress levels and shorten bearing life. The findings provide insights for optimizing bearing design, highlighting the importance of selecting appropriate dimensions and materials to enhance durability and reliability.

Keywords: roller bearings; contact pressure; Von Mises stress; fatigue life; Basquin's equation

Acknowledgement

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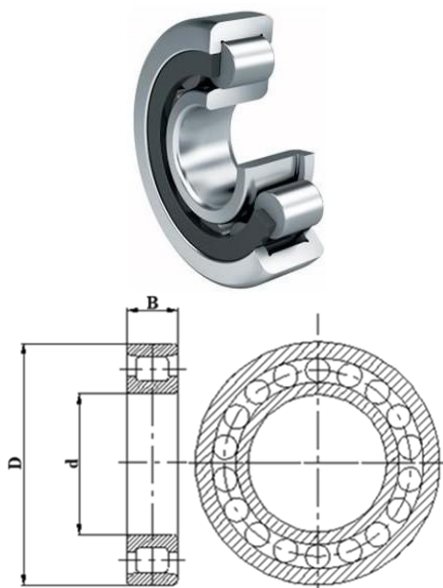


Figure 1. Roller bearing

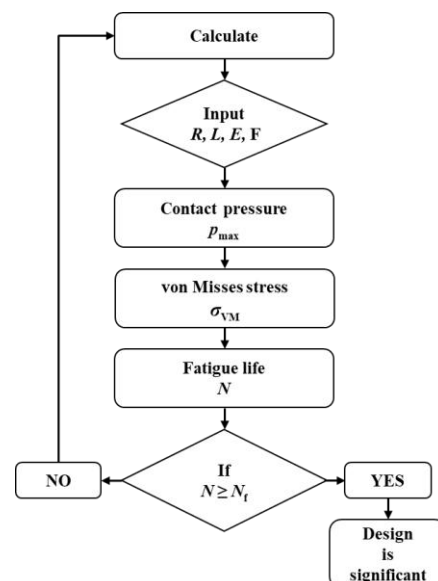


Figure 2. Flow chart of the fatigue life calculation of a roller bearing

EXPERIMENTAL CHARACTERIZATION AND PHASE-FIELD IMPLEMENTATION OF ANISOTROPIC HYDROGEN-ASSISTED FRACTURE IN LAYERED METALS

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Abstract

This work presents an experimental and numerical framework for modeling anisotropic hydrogen-assisted fracture behavior in layered metals using phase-field methods. Traditional isotropic models fail to capture directional variations in crack resistance that arise from manufacturing processes such as rolling or thermal treatment. In addition, the susceptibility of anisotropic metals to hydrogen embrittlement strongly depends on the microstructure orientation.

To address this, an anisotropic phase-field formulation is adopted following the work of Teichtmeister et al. (2017) [1], in which a second-order tensor modulates the crack-driving energy to reflect direction-dependent fracture toughness. The model is implemented in a finite element framework using COMSOL Multiphysics, where coordinate transformations account for local variations in material orientation. Calibration of the tensor components is informed by mechanical characterization of duplex stainless steel (DSS2205), including standard fracture tests (e.g., SENB and CT geometries) performed on specimens extracted along different orientations.

Additionally, mesoscale simulations based on representative volume elements (RVEs) are used to incorporate microstructural effects into the fracture response. These models integrate topological descriptors of the duplex microstructure to account for morphology-induced anisotropy in crack growth. The framework also includes the coupling of fracture and hydrogen diffusion, enabling the simulation of environmentally-assisted cracking phenomena under hydrogen exposure.

This approach enables the simulation of realistic crack trajectories in anisotropic structures and serves as a foundation for more accurate integrity assessments of metallic systems exposed to complex degradation environments.

Keywords: phase-field fracture; anisotropy; hydrogen embrittlement; duplex stainless steel; tensor calibration

Acknowledgement

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FRACTURE OF CRACKED WELDED JOINTS ANALYSED BY DIGITAL IMAGE CORRELATION

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Abstract

Two welded plates with a surface crack, one in heat-affected-zone (HAZ) and the other one in weld metal (WM), were loaded in tension until complete fracture. Digital image correlation (DIC) was used to measure strains and to analyse crack growth. Initial crack length was $2a=30$ mm and depth 6.5 mm in both cases, whereas plate thickness was 13 mm and width 40 mm. Base material (BM) was pipeline steel X60, with yield stress 450 MPa, tensile strength 600 MPa and elongation 22%. Both plates failed dominantly due to the net section extensive yielding, as expected for this type of steel and its welded joints, even in the presence of relatively large crack. Numerical simulation was performed as well to calculate crack driving force and to construct Failure Assessment Diagram (FAD). Results obtained numerically were in good agreement with the experimental ones.

Keywords: Welded joints; digital image correlation; surface crack; crack driving force

MISMATCHING EFFECTS ON FRACTURE BEHAVIOR OF WELDED JOINTS MADE OF HIGH STRENGTH STEELS

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Abstract

Mismatching effects on fracture behavior of welded joints made of High Strength Low Alloyed (HSLA) steel are presented. Mismatching is presented here for both cases, undermatching and overmatching. In the first case, SUMITEN SM 80P HSLA steel welded joints with so-called small and large crack in weld metal are analyzed by using the J integral determined by direct measurement, as well as by using the 3D finite element method (FEM). In the second case St.E420 steel welded joints are analyzed in the same way with a focus on the effect of crack tip location, which was in the fine-grained heat-affected-zone (FG HAZ) in one case, and in the coarse-grained heat-affected-zone (CG HAZ) in the other one. In this way, a complete insight in the effects of mismatching were achieved.

Keywords: Mismatching effect; high-strength low-alloyed steel; Finite element method; Heat affected zone

INTERPRETABLE PREDICTION OF SAMPLE SIZE-DEPENDENT FATIGUE CRACK FORMATION LIFETIME USING DEEP SYMBOLIC REGRESSION AND POLYCRYSTALLINE PLASTICITY MODELS

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Abstract

Fatigue Indicator Parameters (FIPs), derived from cyclic intragranular and intergranular mechanical variables using the Crystal Plasticity Finite Element Method (CPFEM), can serve as surrogate measures of the driving force for fatigue crack formation within the first grain or nucleant phase. Simulating larger sample (i.e., increasing the number of grains) using CPFEM generally results in higher maximum FIP values, indicating a greater likelihood of fatigue crack initiation. However, the substantial computational demands of CPFEM limit its practical application in investigating the sample size effect on maximum FIPs. This study employs the recently developed Deep Symbolic Regression (DSR) algorithm to generate interpretable expressions linking sample size with the statistical characteristics of maximum FIPs in duplex Ti-6Al-4V with random texture. These data-driven expressions obtained through DSR are systematically compared with predictions derived from the statistically grounded Extreme Value Theory (EVT), which suggests that the entire FIP dataset exceeding a threshold x_0 converges to Gumbel distribution. The strong agreements found between DSR and EVT expressions not only validate the mathematical underpinnings of EVT but also demonstrates how EVT can elucidate the physical insights revealed by DSR. Building on this, we introduce a novel method, i.e., Regrouping of Maximum FIPs (RMF), to improve prediction reliability by mitigating the influence of the threshold x_0 in EVT. Finally, by leveraging the statistical distribution of maximum FIPs derived from DSR, we forecast the sample size-dependent Fatigue Crack Formation Lifetime (FCFL), providing a robust tool for engineering applications.

Keywords: Crystal plasticity finite element method; Fatigue indicator parameter; Deep symbolic regression; Extreme value statistics; Fatigue crack formation lifetime prediction

CYCLIC DEFORMATION, HYDROGEN DAMAGE AND CRACK PROPAGATION IN NICKEL-BASED SUPERALLOYS

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Abstract

As strategically important materials, nickel-based superalloys play a crucial role in the aerospace and energy sectors, particularly for manufacturing critical components such as turbine blades and discs of gas turbine engines. Damage tolerance of nickel-based superalloys under fatigue and hydrogen embrittlement conditions is crucial for ensuring the integrity and safety of critical gas turbine components in hydrogen-powered turbine engines. In this study, viscoplasticity and crystal plasticity have been used to model cyclic deformation of nickel-based superalloys at elevated temperature. Model parameters were determined from strain-controlled cyclic test data, with the consideration of varied loading rate. Model simulations were in good agreement with the experimental results for stress-strain loops, cyclic hardening and stress relaxation. Subsequently, the models were coupled with the phase field approach to predict crack growth under fatigue, in comparison with experimental results. Furthermore, computational simulations of hydrogen diffusion have been carried out to quantify hydrogen embrittlement in nickel-based superalloys. A coupled mechanical-diffusion analysis was then developed to account for the interaction between cyclic deformation and hydrogen diffusion under fatigue loading. In conjunction with the phase field method, the coupled model has been applied to predict hydrogen-assisted fatigue crack growth for triangular and dwell loading waveforms, in good agreement with experimental results. The work has significance in structural integrity assessment of hydrogen-powered gas turbine engines with critical rotating components made of nickel-based superalloys.

Keywords: Cyclic deformation; Viscoplasticity; Crystal plasticity; Hydrogen embrittlement; Crack growth

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CRASHWORTHINESS EVALUATION OF A RAILWAY COACH: NUMERICAL STUDY TOWARD CERTIFICATION AND FAILURE MITIGATION

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Abstract

Ensuring structural integrity and passenger safety in railway vehicles requires compliance with strict crashworthiness standards, such as EN 15227. This study aims to evaluate the crash performance of a railway coach under a head-on collision scenario to support certification and explore potential design improvements for failure mitigation.

Finite Element Method (FEM) simulations were carried out using an explicit dynamic approach in Altair RADIOSS. The numerical model reproduces the structural behaviour of a full-scale coach during impact against a rigid wall, allowing detailed assessment of deformation modes and energy absorption. Two configurations were analysed: a baseline structure and a modified version incorporating targeted structural enhancements.

Results were evaluated according to the main criteria of EN 15227, including survival space preservation and deceleration limits. The modified structure demonstrated improved survival space performance, though with slightly higher deceleration levels, consistent with its increased global stiffness. The study highlights how virtual crash testing supports early failure analysis and guides design optimisation for safer, regulation-compliant railway vehicles.

Keywords: Crashworthiness; Transportation; Railway; FEM; EN 15227

Acknowledgement

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AS-BUILT CAD MODELS: A TOOL FOR FATIGUE LIFE PREDICTION OF ADDITIVELY MANUFACTURED STRUT- BASED LATTICES

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Abstract

Despite the remarkable advantages of metal additive manufacturing (MAM) in enabling the efficient fabrication of complex and multifunctional geometrical architectures, such as lattice structures, the printing process inherently introduces a certain degree of defects. These imperfections, often associated with surface roughness, parasitic masses, dross formation, and internal flaws, critically degrade the fatigue performance of additively manufactured components. Nevertheless, such detrimental effects are frequently overlooked during the design phase, where structural optimization typically neglects the actual as-built morphology. Consequently, full-scale testing of MAM lattice structures often fails to capture the true local failure mechanisms ruled by the interplay among geometry, surface features, and internal defects.

To address these limitations, recent research has increasingly focused on miniaturized specimens that reproduce the fundamental sub-unit features of strut-based lattices, such as individual struts and junctions, thereby enabling accurate microscale mechanical characterization while reducing experimental cost and time. In this work, we propose a novel and cost-effective methodology for predicting the fatigue behavior of such sub-unit elements without resorting to expensive monitoring techniques like X-ray Computed Tomography (CT). The approach integrates stereo-optical surface reconstruction with CAD and implicit modeling workflows to accurately reproduce three-dimensional strut geometries. Finite Element (FE) analyses of these reconstructed models are evaluated using the average strain energy density (ASED) criterion and validated against both CT-based FE models and experimental results, establishing correlations through an ASED–Nf relationship derived from bulk Ti-6Al-4V L-PBF specimens. This framework represents an initial step toward defining a robust pathway to bridge microscale and macroscale mechanical behavior, ultimately enabling fatigue-tolerant and cost-efficient lattice designs that can accelerate the industrial adoption of MAM technologies.

Keywords: metal additive manufacturing; strut-based lattice; average strain energy density, finite element analysis

DYNAMIC RESPONSE AND INTEGRITY ANALYSIS OF OFFLOADING ARM STRUCTURE UNDER DIFFERENT LOAD CONDITIONS

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Abstract

This paper performs a transient dynamic analysis of an LNG offloading arm structure on the ANSYS Workbench platform, with the aim of investigating its mechanical response and structural integrity under different loading conditions. A three-dimensional simulation model of the offloading arm was developed, in which complex joint configurations were properly simplified and equivalenced. The model was then imported into ANSYS Workbench, and the finite element analysis module was employed to systematically capture the dynamic evolution of equivalent elastic strain and equivalent stress under various loading scenarios. Based on an in-depth analysis of the simulation results, the structural strength and deformation behavior of the offloading arm under transient loads were evaluated, thereby providing a theoretical foundation for structural integrity design and safety assessment.

Keywords: LNG offloading arm; transient dynamic analysis; force characteristics; ANSYS Workbench; structural integrity design

A PROBABILISTIC METHODOLOGY FOR FATIGUE LIFE PREDICTION UNDER DIFFERENT SPECIMEN SIZE AND CRITICAL PARAMETER DISTRIBUTION

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Abstract

The size effect has been the subject of numerous studies in the literature due to its recognized impact on fatigue life. In the present work, both the size effect and the non-uniform distribution of the failure-governing parameter in the specimen are addressed by taking advantage of the probabilistic Castillo-Canteli fatigue model. To this end, the proposed methodology by the authors, referred to as the Generalized Local Model, is first introduced and subsequently applied to estimate fatigue life in specimens of different types and sizes. The approach is validated for various specimen geometries and loading conditions, including uniaxial fatigue specimens with circular cross-section, specimens with rectangular central cross-section, and rectangular specimens under three- and four-point bending. The results demonstrate not only the validity of the proposed methodology, but also its robustness in deriving the probabilistic S–N field, even in cases where the distribution of the critical parameter is highly complex.

Keywords: Size effect, SN field, Probabilistic fatigue, Generalized Local Model

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MULTIAXIAL FATIGUE LIFE PREDICTION OF HOT-DIP GALVANIZED STEEL BOLTED JOINTS UNDER DIFFERENT GEOMETRICAL CONFIGURATIONS AND LOAD CONDITIONS

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Abstract

Due to their greater flexibility compared to other traditional joining methods, bolted connections are gaining increasing relevance in the industry. Nevertheless, despite the numerous advantages they offer, their inherent complexity, both geometric and stress distribution related, makes them particularly susceptible to multiaxial fatigue failures. This work presents the analysis of an extensive experimental campaign previously carried out by the authors on hot-dip galvanized bolted connections made of S350 GD steel, considering different bolt patterns, tightening conditions, and axial loading ratios. The results are evaluated using various multiaxial fatigue criteria, with the main objective of identifying which criterion provides the best performance for this type of connection and under which specific conditions.

Keywords: Multiaxial fatigue, Bolted joints, FEM fatigue

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PROPAGATION OF MULTIPLE FATIGUE CRACKS IN THIN-WALLED STRUCTURES

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Abstract

In thin-walled structures fatigue cracks may initiate at stress concentration sites due to cyclic service loads. Multiple site damage (MSD) typically occurs in aged thin-walled structures such as aircraft, ship and other structures, where fatigue cracks appear at sites of geometric discontinuities, and further propagate into the skin structure. After cracks reach a critical crack length, fracture of the structural element occurs, which can result in loss of structural integrity and structural failure.

Here are presented experimental and numerical simulation analysis results of propagation of multiple fatigue cracks in plates and stiffened panels under cyclic tension. Fatigue crack propagation tests with constant stress range and frequency were carried out for a plate with a single center crack and a plate with three collinear cracks. The experiment showed that crack tips in the specimen with three cracks propagate at different propagation rates. In order to take into account in simulations the different crack propagation rates, observed in the experiment, an interactive crack propagation simulation procedure for multiple propagating crack tips was implemented. The procedure is based on the numerical integration of the Paris equation, where the stress intensity factor values are calculated by a FEM program. The simulated fatigue crack growth life for the plate specimen with three cracks was in good agreement with the experimental results, showing that the introduced simulation procedure takes into account the interaction of propagating crack tips properly.

Keywords: Fatigue; Multiple cracks; Crack propagation; Interaction

FINITE ELEMENT MODELLING OF MODE-I DELAMINATION OF CURVED CFRP COMPOSITE PANEL USING COHESIVE ZONE MODEL

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Abstract

Laminated composites are commonly used to replace metals in various engineering applications, including aircraft, spacecraft, automobiles, and sports devices, due to their high specific strength and specific stiffness. Despite their advantages, these composites are prone to delamination or interlaminar fractures caused by multiple factors, such as more interlaminar stress, impact forces, and stress concentrations, as well as manufacturing imperfections. The present study is carried out to simulate mode I delamination of curved Carbon Fiber Reinforced Polymer (CFRP) panels using the cohesive zone model (CZM). The critical force for delamination is compared with flat CFRP double cantilever beam (DCB) specimen results obtained from simulation and available experimental data in the literature. CZM is a handy tool used in the finite element method (FEM) that predicts the critical delamination load more accurately towards the experimental result. In this paper, CZM is implemented using Abaqus software, using a cohesive contact surface behavior to estimate the critical force for delamination in a CFRP double cantilever beam. Mode I delamination of the curved CFRP panel was carried out for different arc angles in the cross-section, and the variation of forces was obtained at the angle of the arcs of the curved panels. The effect of curvature in cross-section for mode I delamination is studied compared to a flat laminate. Cohesive surface contact using traction-separation laws is implemented, in which an initial linear elastic phase is present and proceeds to a linear softening phase to simulate interface delamination after damage initiation.

Keywords: Delamination; Mode I; Cohesive contact surface; Double Cantilever Beam (DCB); Curved panel

SOFTWARE DEVELOPMENT FOR ANALYZING VARIATIONS IN THE COEFFICIENT OF FRICTION DURING RECIPROCATING MOTION

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Abstract

Software has been developed to analyze variations in friction coefficients during reciprocating motion of a ball-on-flat contact pair (ball Al₂O₃ Ø9 mm, plate – steel 17Mn1Si, load 10 N, stroke length 16 mm, period 6 s), including static, dynamic, and integral coefficients of friction. The software applies robust time-series segmentation, outlier filtering, and normalization, followed by polynomial and spline-based curve fitting for precise and stable reconstruction of experimental friction data.

The variation of friction coefficients during reciprocating motion can be described by modulated cosine curves, where positive and negative values correspond to motion in opposite directions. The friction coefficient values at the points where the counterbody reverses direction corresponds to the static friction coefficient. During the counterbody motion along the friction track, oscillations in the dynamic friction coefficient are recorded. These oscillations depend on the surface condition (topography, surface films) and external factors such as contact pressure, environment, and temperature.

A detailed analysis of the variation in friction parameters under the influence of different factors is essential for understanding the mechanisms of friction and wear in materials.

To improve the methods of evaluation and statistical analysis of friction coefficients, an interactive algorithm has been developed that enables the following:

- separation of friction coefficient values corresponding to the indenter movement in the forward and reverse directions;
- statistical processing of a variable number of experimental data points to determine the average value of the dynamic friction coefficient within each stroke;
- evaluation of friction coefficient oscillations within each stroke, allowing the tracking of changes in the nature of frictional interaction during the running-in stage or when the friction mechanism changes;
- establishment of an analytical relationship describing the variation of the averaged friction coefficient over time.

During tribocorrosion, periodic fluctuations in the electrochemical potential of the friction surface are observed in parallel with changes in the friction coefficients. These fluctuations are caused by the formation, transformation, and removal of surface films, as well as by the appearance of freshly exposed (juvenile) surfaces and the formation of galvanic couples. Analyzing the influence of various factors on the dynamics of the friction coefficient and electrode potential makes it possible to identify correlations between them and to reveal the underlying mechanisms of tribocorrosion.

Keywords: software; coefficient of friction; reciprocating motion; oscillation; approximation

MODELING FOR MECHANICAL PROPERTIES OF PARTICLE-FILLED COMPOSITE MATERIALS

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Abstract

This study focuses on the mechanical properties of particle-filled composites, where the matrix material is a polymer resin and the filler particles are metallic. It is crucial to investigate the intrinsic strength and internal damage fracture behavior of composite materials for engineering applications. Uniaxial tensile tests at loading speeds from 1 – 3000 mm/min were conducted to characterize the strength and fracture behavior of the composite. A novel n-dimensional hyperspherical particle-filled method was developed for composites modeling, and a micro-macro analysis method for simulating the failure process was proposed. A classical viscoelastic constitutive model, consisting of a spring element in parallel with a generalized Maxwell model, was adopted to describe the polymer matrix behavior. The phase field fracture method was employed to simulate the failure process of particle-filled composites. Machine learning techniques were applied to optimize the constitutive parameters by integrating uniaxial tensile test results at different strain rates. As shown in Figure 1, a meso-to-macro scale framework was established to predict the strength and failure of the investigated particle-filled composites, effectively accounting for material heterogeneity.

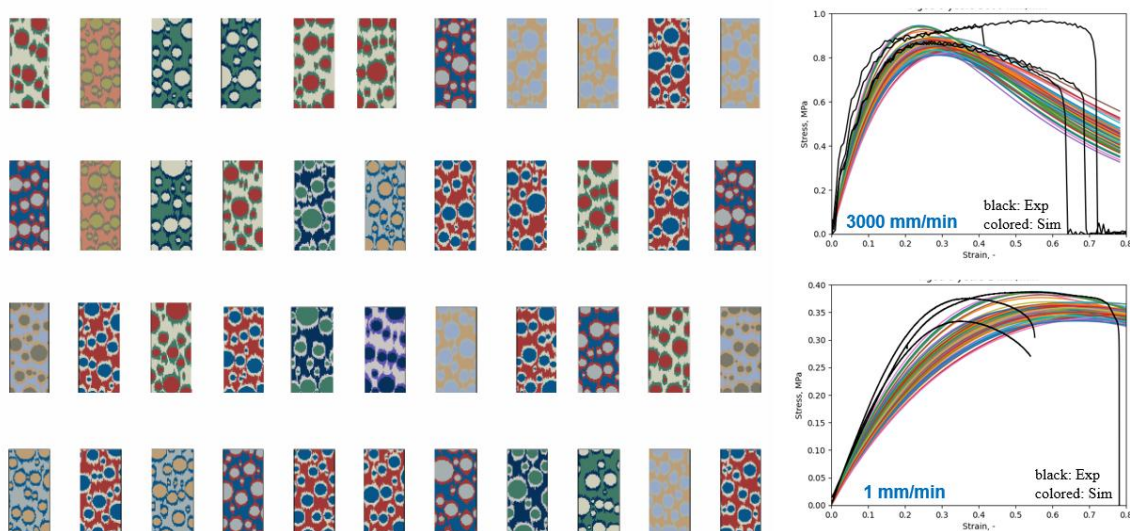


Figure 1. Viscoelastic phase field fracture gradient damage model for particle-filled composites and interface.

Keywords: Particle-filled composite; Viscoelastic constitutive model; Phase field fracture

NUMERICAL SIMULATION OF HYDROGEN EMBRITTLEMENT COUPLING IN L245 STEEL PIPELINES

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Abstract

Hydrogen transport by long-distance pipelines shows good merits of large-capacity and low-cost transportation. However, welding residual stress of pipelines plays a great role in promoting hydrogen enrichment and HIC caused by it in weld-joints. The hydrogen enrichment problem in the welds of L245 steel was investigated using both field testing and finite element (FE) methods. Residual stresses at the welds of L245 pipeline steel were measured using the hole-drilling method. A finite element model was developed for a welded joint in a $\phi 610 \times 15.9$ mm L245 pipe section, consisting of seven welds. The element birth-and-death method was employed to simulate the welding process, and a thermo-mechanical coupling method was used to obtain the welding residual stresses. Using secondary development in ABAQUS, the effect of welding residual stresses on hydrogen concentration distribution was studied, utilizing the hydrogen diffusion coefficient obtained from experiments. The results show that the predicted residual stresses at the weld point match the experimental data very well. The circumferential and axial residual stresses reach their maximum values at the fifth weld, with values of 342 MPa and 296 MPa, respectively. The combined effects of the concentration gradient and stress gradient drive hydrogen atoms into the interior. For the hydrogen diffusion model of the six-layer, seven-weld joint, hydrogen atoms primarily accumulate at the fifth weld.

Keywords: Numerical simulations, welding residual stress, hydrogen enrichment, welding speed

ENGINEERING DAMAGE MECHANICS

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THERMOELASTIC STRESS EVALUATION OF FUNCTIONALLY GRADED ANNULAR DISCS UNDER COMBINED THERMAL AND PRESSURE LOADS USING FINITE DIFFERENCE METHOD

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Abstract

This paper presents a numerical investigation of the elastic stress distribution in annular discs composed of functionally graded materials (FGMs) using the Finite Difference Method (FDM). The discs are subjected to uniform internal pressure and a radially varying temperature field that decreases linearly from the inner to the outer surface. The material properties, including young's modulus and the coefficient of thermal expansion, are assumed to vary along the radial direction following power-law functions, while Poisson's ratio remains constant. The governing equilibrium equations are expressed in terms of the airy stress function and solved numerically using finite difference discretization under suitable boundary conditions. The study examines the effects of gradient parameters on radial and circumferential stresses, as well as on radial displacement. The results indicate that both the material gradation and the temperature distribution significantly influence the thermo-elastic behavior of the FGM disc, offering useful insights for the efficient design of high-performance rotating components such as brake and turbine discs.

Keywords: Annular disc; Finite Difference Method (FDM); Functionally graded material (FGM); Thermal stress; Radial pressure

RESIDUAL STRESS RELEASE MECHANISM AND THEORY ON POST WELD HEAT TREATMENT OF PRESSURE VESSELS

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Abstract

Welding residual stress is the primary cause of stress corrosion cracking, creep failure, and fatigue damage in large pressure vessels. Heat treatment has become an effective approach to relieve such welding-induced residual stresses. Currently, the pressure vessel are becoming extremely large in diameter, thickness and length, Due to limitations in furnace size, special structures, in-service repair welding, etc., large pressure vessels often cannot undergo integral heat treatment and require local post-weld heat treatment (LPWHT). However, the applications of LPWHT may result in detrimental effects without proper process optimization. In this paper, the evolution of residual stresses during overall and local heat treatment considering creep effects is given for large pressure vessels. The results show that creep is a key factor in regulating residual stresses during the integral heat treatment. The release of welding residual stresses occurs mainly in the heating stage. When the heat treatment temperature reaches the creep temperature, the residual stress is rapidly released in a short period of time and remains largely unchanged during the holding stage. The residual stress evolution pattern during the heating and cooling stages of local heat treatment is quite different from the integral heat treatment. During the cooling stage, due to the cold-end constraints from unheated regions and the effect of axial temperature gradient, waist-contracting deformation occurs, generating significant secondary tensile stress on the inner wall, which leads to the ineffective relief of the inner wall stress. To address the above issues, this paper establishes an analytical solution for the stresses and deflections induced by local heat treatment of pressure vessels, and presents process criteria to approximate the residual stress relief effect of integral heat treatment. Furthermore, a primary-secondary local heat treatment method and theoretical model are proposed. Through theoretical derivation, the optimal process parameters for maximizing residual stress relief are determined, and a process design approach to induce compressive stress on the inner wall.

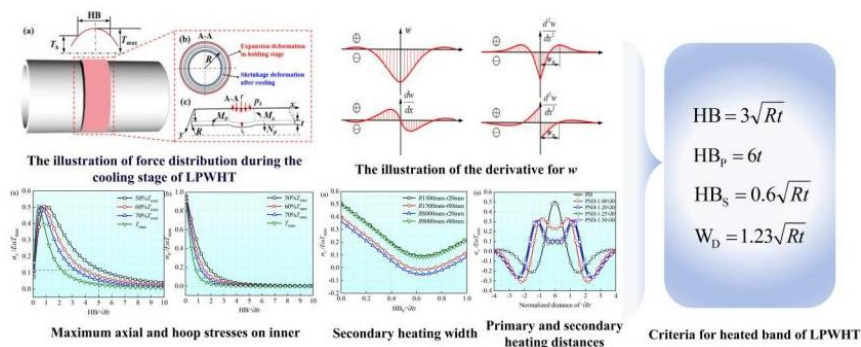


Figure 1. Process and results of the theory on local post weld heat treatment of ultra-large pressure vessels

Keywords: Local post weld heat treatment; Width of heated band, Residual stress; Primary plus secondary local post weld heat treatment



Acknowledgement

The authors gratefully acknowledge the support provided by the National Science Foundation for Distinguished Young Scholars of China (52325502) and National Natural Science Foundation of China (U21B2076).

COMPARATIVE EVALUATION OF EXPERIMENTAL AND PHASE-FIELD MODELING APPROACHES IN THE TENSILE RESPONSE OF S1100QL STEEL

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Abstract

Phase-field Damage Modeling (PFDM) has gained considerable attention as a robust framework for representing material degradation and failure. Its capacity to describe the progressive evolution of damage has led to increasing integration into finite element method (FEM) codes, establishing PFDM as a promising tool for structural assessment. In this study, an axisymmetric PFDM formulation is implemented and validated through comparison with experimental tensile tests on high-strength S1100QL steel specimens.

Cylindrical specimens were machined from the base material using CNC lathes to determine its tensile properties. The tensile tests were subsequently performed on a universal testing machine, ZWICK ROELL Z/100 (ZWICKROELL GmbH, Ulm, Germany) (Fig. 1a).

The critical-total strain-based PFDM implemented into the software PAK-DAM v25 is used for numerical analysis of tensile tests. For numerical simulation, an FE model was created using 2D axisymmetric finite elements. The simulation was performed using the large strain von Mises plasticity constitutive model and logarithmic strain measure. The created FE model consists of 970 elements and 1078 nodes. The FE model, boundary conditions, and loading of the specimen are given in Fig. 1b.

In Fig. 1c, a comparison of the stress-strain diagram for the numerical simulation and the experiment is given. The results show good agreement between the experiment and the numerical simulation results.

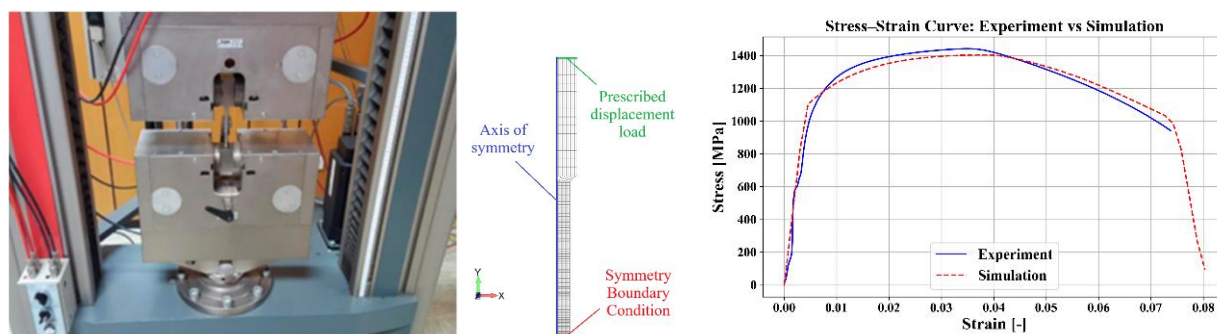


Figure 1. a) ZWICK ROELL Z/100 testing machine; b) FE Model with boundary conditions and loads; c) comparison of stress-strain diagram for experiment and numerical analysis

Keywords: Finite Element Method; Phase-Field Damage Model; S1100QL Steel; PAK-DAM

Acknowledgement

This research is supported by the Science Fund of the Republic of Serbia, #GRANT No 7475, Prediction of damage evolution in engineering structures – PROMINENT, and by the Ministry of Science, Technological Development and Innovation, Republic of Serbia, Agreement No. 451-03-137/2025-03/200107.

SIMPLIFIED SPSI ANALYSIS OF CEMENT SILOS EXPOSED TO LIQUEFACTION

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Abstract

The analysis of the interaction of the structure and the soil, in some specific cases, has been known since ancient times, but concrete application to engineering design began only at the end of the 19th century, and serious development began only in the second half of the 20th century. The paper presents some simplified SPSI methods, as well as static analysis and the effect of liquefaction. During the Hokkaido Nansei-Okai earthquake with a magnitude of 7.8, in Japan in 1993, liquefaction occurred on the filled soil in Hakodate Port. Of the 2 silos, one larger with a mass capacity of 5,000 t, and the other in the immediate vicinity, with a mass capacity of 2,500 t, the smaller one experienced significant settlement and rotation. Due to local lateral spreading, 1/20 tilt and 90 cm differential settlement occurred. Cement silo with a mass capacity of 2,500 t was supported on 64 pre-stressed concrete piles. All piles experienced fracture. The damaged silo superstructure, was urgently demolished, so as not to damage neighboring buildings. Mori and Numata performed detailed analyzes of the piles of this silo, after demolition, including displacement, acceleration, shear stress, shear strain and excess pore water pressure ratio. The same authors also provide models of interaction with the spring system, such as Gazetas, Mylonakis, Tazoh, Novak, Nogami, Penzien, Wilson, etc.

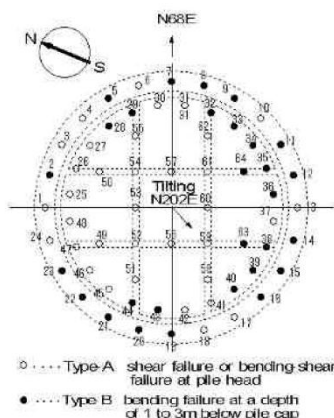


Figure 1. Variation of the two failure patterns

Keywords: SPSI; Vertical pile interaction, Liquefaction, Lateral spreading, pile failure/fracture mechanism, pore water pressure (EPWP) ratio, CRR, CSR.

Acknowledgement

This work was supported by the Ministry of Science and Technological Development and Innovation of the Republic of Serbia (Contract No. TNR font size 451-03-136/2025-03/ 200213).

INFLUENCE OF STRESS CONCENTRATION AND ENVIRONMENTAL CHAMBER VOLUME ON HYDROGEN EMBRITTLEMENT SUSCEPTIBILITY OF L245 PIPELINE STEEL GIRTH WELD

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Abstract

The spatial imbalance between upstream hydrogen production and downstream hydrogen utilization hinders the development of hydrogen energy as a green and clean energy source. Although the construction of pipeline networks for hydrogen transportation involves high initial investment, it better aligns with long-term policy requirements and facilitates the sustainable development of the hydrogen energy industry. Welding of pipeline girth welds induces changes in microstructure and mechanical properties, often leading to unavoidable welding defects. The accumulation of hydrogen atoms in stress concentration zones formed by these defects increases the susceptibility to hydrogen embrittlement. In this study, notched tensile specimens of L245 pipeline steel in girth weld was selected to slow strain rate tensile tests in 6.3 MPa hydrogen and nitrogen environments, respectively. The variation of hydrogen embrittlement susceptibility of weld metal with different stress concentration coefficients was investigated, and fracture surfaces were characterized using scanning electron microscopy (SEM). The results indicate that the hydrogen embrittlement susceptibility of the weld metal does not increase monotonically with the stress concentration coefficient; instead, it decreases when the stress concentration coefficient exceeds a certain value. Macroscopic and microscopic morphological analyses were employed to elucidate the damage mechanisms. The study also reveals that the volume of the environmental chamber has a direct impact on the results. These in-depth researches contribute to enriching laboratory data on hydrogen transmission pipeline steels, supports the establishment of engineering evaluation standards for welding defects in hydrogen pipeline construction, and provides a foundation for the integrity assessment of hydrogen pipeline infrastructure.

Keywords: Hydrogen transmission pipeline; Girth welds; Stress concentration; Hydrogen embrittlement sensitivity; Cleavage fracture

ON THE DISTINCTION BETWEEN BLUNT AND SHARP NOTCHED: REVISITING THE CONCEPT OF LIMIT NOTCH RADIUS THROUGH THE AVERAGED SED METHOD

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Abstract

Dealing with mechanical components, their functional requirements often lead to geometrical discontinuities, which in turn create significant stress concentrations and gradients. These discontinuities, commonly known as notches, negatively impact the structural reliability and fatigue strength of the entire component. It is well established that, depending on the notch severity, traditional point stress-based approaches can substantially overestimate the detrimental effects on the fatigue performance. Consequently, notches are typically classified as either blunt or sharp, with the fatigue behavior of sharp notches being poorly captured by stress-based point approaches. To address this limitation, numerous studies have attempted to define the boundary between blunt and sharp notch behavior and to develop design methodologies that effectively capture both conditions. One of these methods is the averaged Strain Energy Density (SED) method, widely recognized for its accuracy across both notch types. In this study, the SED method is applied in the attempt to identify a limiting condition, defined in terms of a limit notch radius, , capable of distinguishing between blunt and sharp notches. The proposed limit condition has been hence examined through numerical simulations and validated against an extensive fatigue database retrieved from existing literature.

Keywords: Fatigue; Notch-mechanics; Averaged SED method; fatigue notch-strength; limit notch radius

Acknowledgement

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LOCAL LIMIT LOAD FOR RPV NOZZLES WITH CORNER CRACKS UNDER COMBINED INTERNAL PRESSURE AND NOZZLE EXTERNAL LOADS

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Abstract

The limit loads of typical cylinder nozzles with an internal corner crack under combined internal pressure, nozzle axial force and nozzle bending moment are investigated. A plate model with a through-wall crack representing the nozzle hole and the corner crack is recommended for estimating the local limit loads of the corner crack under complex loading conditions. This model is verified by comparing the J values estimated via the reference stress method in R6 using the local limit loads obtained from the plate model and the elastoplastic FE J results for 320 cases. The results show that the FE J results can be predicted reasonably and conservatively by the reference stress method when the local limit load is used. In other words, the local limit load estimated using the plate model is conservative when it is used in structural integrity assessment of the nozzle structures with corner cracks.

Keywords: nozzle corner cracks; local limit load; combined loading; J-integral

HFMI EFFICIENCY UNDER VARIABLE LOADING

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Abstract

Previous studies have repeatedly confirmed that the HFMI method significantly increases the fatigue life of welded joints under constant amplitude loading (CAL). The follow-up work focused on investigating the effectiveness of the HFMI method when subjecting welded joints to variable amplitude loading (VAL).

Welded T-specimens were tested, with HFMI applied to one group of samples, while the other group remained untreated. Experimentally obtained fatigue lives in VAL-type tests were compared with theoretical predictions, which made it possible to calibrate the Palmgren-Miner rule.

Although the fatigue tests were performed with a smaller number of test samples, the findings can be considered proven. It was confirmed that the HFMI method significantly increases the fatigue life of welded joints even under variable amplitude loading. At the same time, it was found that in order to achieve higher reliability of fatigue life predictions of welded structures under their real operational loads, it is necessary to perform VAL-type tests.



Figure 1. Application of HFMI technology and a test specimen in the test stand

Keywords: weldments; fatigue life; HFMI, variable loading; Palmgren-Miner rule

Acknowledgement

The contribution has been prepared with the institutional financial support of the Ministry of Education, Youth and Sport of the Czech Republic.

A COUPLED DAMAGE CONSTITUTIVE MODEL FOR CARBIDE-FREE BAINITIC RAIL STEEL CONSIDERING MARTENSITE TRANSFORMATION

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Abstract

The fatigue resistance of the widely used pearlite heavy haul rail has reached the theoretical upper limit, and the carbide-free bainite (CFB) steel with more excellent wear resistances and fatigue resistance is considered as a new generation of heavy-haul steel to replace the pearlite steel. And the fatigue damage evolution of CFB rail steel is highly complicated due to its unique deformation mechanisms and ratcheting-fatigue interaction. Considering the influence of phase transformation and damage on the whole-life ratcheting behavior, a damage-coupled cyclic plastic constitutive model of CFB rail steel is established. The isotropic resistance and back stress of transformation hardening caused by plastic deformation are introduced into the driving force of phase transformation to consider the influence of plastic deformation on the phase transformation deformation, and the reasonable description of martensitic transformation in cyclic softening materials is realized; furthermore, the martensitic volume fraction and maximum equivalent plastic strain are coupled with the failure strain and damage index respectively in the damage evolution equation to consider the adverse effect of phase transformation on fatigue life and the acceleration effect of ratcheting deformation on damage evolution; Meanwhile, Tanaka's non-proportional parameter is introduced into the evolution equations of failure strain and damage index to consider the influence of non-proportionally multiaxial loading path on damage evolution. The model can reasonably describe the damage variable and evolution of martensitic volume fraction during cyclic loadings, and accurately predict the fatigue life of the material under different loading conditions, which can provide theoretical guidance for the evaluation of long-life service behavior of CFB rail during rolling contact.

Keywords: Carbide-free bainitic steel; Ratcheting-fatigue interaction; Coupled damage; Phase transformation; Cyclic plastic constitutive model

Acknowledgement

Financial supports by the National Key Research and Development Project (2025ZD0611000), National Natural Science Foundation of China (U21A20167, 12192210, 12192214, 11872321), Sichuan Provincial Natural Science Foundation (2025ZNSFSC0008), Independent Project of State Key Laboratory of Rail Transit Vehicle System (2023TPL-T03) and Postdoctoral Fellowship Program of CPSF (GZC20240702) are acknowledged.

NUMERICAL MODELING AND DAMAGE PREDICTION IN HSLA PREMIUM CONNECTIONS USING A MINI-STRUCTURE

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Abstract

Ensuring the structural integrity and sealing performance of premium connections in oil and gas applications is a major challenge due to complex loading conditions and limited access for inspection. This study presents a numerical approach to predict plastic strain accumulation, damage initiation, and residual stress distribution in high-strength low-alloy (HSLA) steel connections using a representative mini-structure.

The methodology relies on the open-source finite element software Code_Aster. An elastoplastic constitutive model combined with the Gurson–Tvergaard–Needleman (GTN) damage law was first calibrated on a standard tensile specimen using experimental data. The validated model was then applied to a newly designed mini structure that replicates the heterogeneous stress fields observed in full-scale connections.

The mini-structure geometry integrates features of the connection teeth and generates multiaxial stress states, enabling the identification of material parameters from a single test. Simulation results show strong agreement with stress and strain distributions in actual connections, confirming the mini-structure's relevance for damage prediction. The study also outlines an inverse identification strategy using Digital Image Correlation (DIC) for future experimental validation.

This approach offers a cost-effective and reliable framework for improving the design and safety of premium connections under complex service conditions.

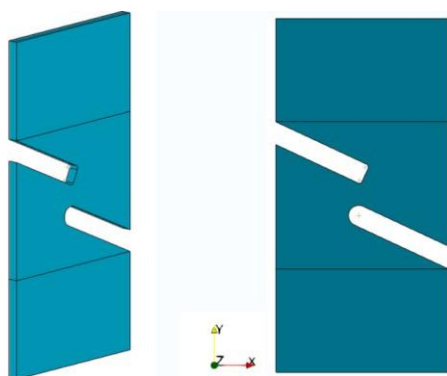


Figure 1.a Mini structure

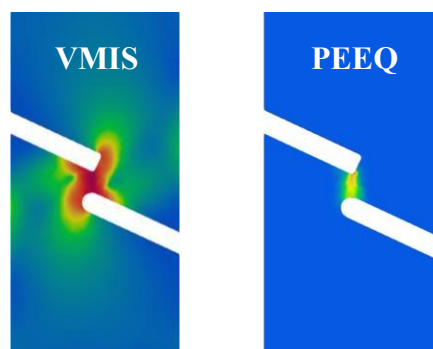


Figure 1.b Mini structure : Von-Mises ; PEEQ

Keywords: Damage modeling; GTN model; Mini structure; Premium connections; Finite element simulation

CONSTITUTIVE RESPONSE MODELLING FOR METALLIC MATERIALS UNDER IMPACT LOADING ACROSS A WIDE TEMPERATURE RANGE

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Abstract

Metallic materials exhibit complex constitutive behaviour across a wide range of temperatures and strain rates. Beyond the familiar rate sensitivity and thermal softening, other coupled rate-temperature phenomena, such as thermal hardening, strain softening, and yield drop, can arise, particularly at high strain rates. To capture the coupled rate-temperature effects, the rate-temperature correspondence is usually considered. It assumes that the increase in stress caused by high strain rates can be effectively modeled by reducing the temperature. Mathematically, this relationship is often expressed in the multiplicative form. Empirical models of this type, such as the Johnson–Cook model and its modifications, are typically created by introducing additional empirical components—dependent on strain rate and temperature—into classical models originally developed for quasi-static conditions. However, experimental studies show that these models prove inadequate for accurately describing the stress–strain curves of metallic materials over a wide range of temperatures and strain rates, since they lead to a temperature-independent the relative stress factor, which contradicts the experimental observation.

The relaxation model of plasticity (RP model) developed by authors considers the rate sensitivity of materials as a manifestation of their time sensitivity. Unlike the empirically based Johnson–Cook formulation, it was derived from the concept of incubation time (or characteristic relaxation time). Moreover, instead of relying on the principle of temperature-rate correspondence, this model employs the temperature-time correspondence, which is based on the dependence of the characteristic relaxation time on temperature. The model behaviour is discussed and compared with some representative multiplicative (phenomenological) and additive (physically-based) models, using data for Ti–5Al–5Mo–5V–1Cr–1Fe, L907A steel, Ti–6Al–4V, and DH-36 steel (in fig. 1). The capability of the RP model and its associated numerical algorithms is validated against experimental results for Ti–6Al–4V and the rare-earth magnesium alloy Mg–9Gd–4Y–1Zn–0.5Zr (wt %).

Keywords: Buckingham-Pi theorem; correlation matrix; Strouhal number; synthetic jet actuators

Acknowledgement

This work was financially supported by the Russian Science Foundation (RSF 22-11-00091).

UNCERTAINTY QUANTIFICATION FOR CREEP BEHAVIOR OF P91 STEEL USING GENERALIZED POLYNOMIAL CHAOS EXPANSION AND ARTIFICIAL NEURAL NETWORKS

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Abstract

The creep behavior of materials is of paramount significance for equipment operating in high-temperature environments. However, the inherent uncertainties in such materials pose substantial challenges to the reliability of equipment during long-term service. This study proposes a probabilistic framework to capture the uncertainty of creep performance. The Wilshire-Cano-Stewart (WCS) model is employed to characterize the creep behavior of P91 steel. Generalized polynomial chaos expansion (gPCE) and artificial neural networks (ANNs) are applied to quantify the impact of material uncertainties on creep behavior, with their accuracy validated using data obtained via Monte Carlo simulation. Considering the scale of uncertainties, a comparative analysis of the performance of gPCE and ANNs is conducted. The results indicate that gPCE exhibits advantages in scenarios with a small dimension of uncertainties since fewer samples are required, while ANNs demonstrate good performance in addressing high-dimensional problems. Additionally, operating conditions exert a significant influence on random creep behavior.

Keywords: Creep behavior; WCS model; Uncertainty quantification; Polynomial chaos expansion; Artificial neural networks

FRAMEWORK OF ENGINEERING DAMAGE THEORY AND RECENT PROGRESSES

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Abstract

With the increase of complex service conditions of key-section components used in renewable energy in the context of carbon neutrality, damage modes and failure forms have become increasingly complex and diverse. However, even the most accurate existing life assessment theories, used for evaluating material performance and structural durability, can only passively predict macroscopic behaviors without active regulation capacities. In this research, a full-chain fundamental system for engineering damage theory is established to address this challenge, where an in-depth understanding of the multiscale essence during the mechanical and damage evolution processes until failure of structural materials is investigated. Four subsequent procedures of "deformation mechanism—damage regulation—life prediction—reliability assessment" are implemented to perfecting engineering damage theory. The frontier in this study is to effectively enhance the creep-fatigue lifetimes of relevant structures by integrating multiple disciplines of material science, information science, mechanical science, and management science. By integrating data from various sources, including material testing, computational simulations, and practical conditions, it serves for exploring scientific link between microstructural features and anti-damage strength under creep-fatigue loading conditions. Furthermore, an intelligent life-management platform enables real-time reflections of damage resistance for critical components, providing hardware basis for next-generation engineering equipment digital twin system with active feedback capabilities. Aiming at intrinsic performance promotion, engineering damage theory based on multidisciplinary paradigm facilitates the transformation of materials and structures from "passive" life assessment" to "active life design", thereby enhancing the safety operations of mechanical structures while fully leveraging carbon reduction potentials.

Keywords: Engineering damage theory; Multidisciplinary paradigm; Life design; Creep-fatigue; Carbon neutrality

Acknowledgement

This work is acknowledged and financially supported by MEXT's Strategic Professional Development Program for Young Researchers and NEXUS Research Program in Japan.

CORROSION RESISTANCE OF WELDED JOINT ZONES MADE OF AISI 316L STAINLESS STEEL

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Abstract

The objective of this research is to examine the corrosion behavior of welded joints made from AISI 316L austenitic stainless steel, with a particular focus on general, galvanic, pitting, and intergranular corrosion. A comprehensive experimental approach was applied, including chemical and mechanical characterization, microscopic analysis, and electrochemical testing. The results revealed that variations in microstructure, especially in the heat-affected zone (HAZ), lead to reduced resistance to localized corrosion forms. Electrochemical impedance spectroscopy (EIS) and Tafel analysis confirmed that the corrosion resistance of welded regions was lower compared to the base material. The weld metal (WM) exhibited a slightly more negative corrosion potential, indicating a higher susceptibility to galvanic corrosion. Pitting corrosion resistance was notably diminished in the HAZ, likely due to partial sensitization induced by excessive heat input. Intergranular corrosion tests, including oxalic acid etching and Double Loop Electrochemical Potentiokinetic Reactivation test (DL-EPR) confirmed acceptable behavior of the base material and HAZ, while the weld metal showed increased vulnerability. Furthermore, the potential increased content of CO₂ in the shielding gas might led to surface defects and microstructural changes, contributing to the overall decline in corrosion resistance. These findings highlight the critical influence of welding parameters on corrosion behavior and emphasize the need for precise process control to ensure long-term performance and structural reliability in corrosive environments.

Keywords: AISI 316L stainless steel; corrosion resistance; welded joints; pitting corrosion; MAG welding

Acknowledgement

This work is supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract No. 451-03-68/2024-14/200135, 451-03-136/2025-03/ 200213, 451-03-136/2025-03/200135, 451-03-136/2025-03/200026).

INTERGRANULAR CREEP DAMAGE IN AN AUSTENITIC STAINLESS STEEL: A COUPLED PHASE FIELD - CRYSTAL PLASTICITY STUDY

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Abstract

A novel coupled phase field - crystal plasticity framework is proposed to study intergranular damage during creep in a commercial (HR3C) austenitic stainless steel exposed to different service times. In the formulation, the phase field order parameter, which represents a scalar measure of damage, is driven by both the elastic energy and the stored energy associated with the local dislocation structure. Detailed grain boundary analyses revealed that the primary mechanism responsible for the initiation of creep damage was the nucleation of microcavities at random high-angle boundaries, where carbides and σ -FeCr phases tend to precipitate during service. A novel approach is proposed to account for the critical separation work of grain boundaries (GBs) of either tilt, twist, or mixed tilt-twist character, and it is made to depend on both the surface energy of the newly created intergranular microcavity and the energy of the GB given by an extended Read-Shockley model. The proposed framework relied on representative volume elements of EBSD-based digitally reconstructed microstructures to obtain predictions of creep deformation, damage and ultimate rupture, which were found to be consistent with experimental data. Experimentally observed microcavity sites were also successfully predicted and found to nucleate preferentially at random high angle GBs of mixed tilt-twist character with misorientations ranging from 50° to 60°. Furthermore, good agreement was found between the trends exhibited by the measured and predicted GB cavitation ratios with GB misorientation angle.

Keywords: Intergranular creep damage; Phase field; Crystal plasticity; Finite elements

FRACTURE AND IRREVERSIBLE DEFORMATION IN SOLIDS: STATICS VS DYNAMICS

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Abstract

The traditional quasi-static approach to analyzing dynamic phenomena often creates the illusion of paradoxes where none exist. The features of deformation and fracture of continuous media in dynamics, which are radically different from the usual quasi-static concepts, are discussed. It is demonstrated why classical "equilibrium" models are powerless in explaining many contradictory dynamic effects, and why direct extrapolation of the usual static principles and criteria of fracture to the non-stationary case, even with dynamic coefficients and corrections, often leads to erroneous conclusions.

The main provisions of the incubation time approach to dynamic problems of fracture and irreversible deformation are presented, and the possibilities of its application for predicting and explaining effects arising in various transient processes of mechanics and physics are demonstrated.

It is demonstrated that the integration of physical analysis with classical models of non-stationary dynamics provides a powerful toolkit for understanding and predicting effects that appear contradictory and even paradoxical. This makes it possible to explain complex dynamic phenomena without resorting to the artificial introduction of new entities, and opens up promising directions for further research in the field of solid mechanics.

Keywords: Fracture; irreversible deformation; crack dynamics; incubation time; relaxation process

Acknowledgement

The work was supported by RSF Grant № 22-11-00091.

IDENTIFICATION OF HYDROGEN DIFFUSION AND TRAPPING PARAMETERS FROM PERMEATION TESTS

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Abstract

Hydrogen embrittlement is the umbrella term referring to the mostly reversible degradation of a material's mechanical properties due to interaction with hydrogen. The phenomenon depends on various factors, among which hydrogen concentration plays a central role. Depending on the material and its stress state, increasing hydrogen content can lead to loss of ductility or strength. Identifying or estimating the hydrogen concentration and its distribution is therefore essential for assessing embrittlement risk during manufacturing or service life.

Understanding hydrogen content is equally important for interpreting laboratory tests such as hydrogen-charged SSRT. The transition from ductile to brittle hydrogen-assisted fracture, observed via post-mortem fractography, can only be fully explained when local hydrogen levels are known or estimated. Numerical modeling offers advantages in this context: when temperature and time-history data are available, it can help account for experimental variability and use bulk measurements (e.g., hot extraction) to infer local hydrogen near critical zones. Accurate diffusion and trapping parameters are thus crucial and must be derived experimentally and carefully interpreted.

A new analytical expression is presented for estimating trapping and diffusion properties from partial buildup and decay hydrogen permeation transients. Its key advantage lies in handling multiple traps and accounting for trap saturation effects under the assumptions of the McNabb and Foster model and Oriani's equilibrium. The method's performance is demonstrated against established approaches in the literature, and its advantages and disadvantages with respect to a full simulation based fitting are explained.

Finally, a high-strength steel is characterized using a Devanathan-Stachurski double cell setup with multiple buildup and decay transients in both as-received and pre-strained conditions. The results illustrate how plastic strain alters trapping parameters, which is an essential factor for modeling hydrogen behavior in components exposed to plastic deformation.

Keywords: Hydrogen trapping; hydrogen diffusion; Material modelling; Electrochemical permeation testing; Partial transients

FAILURE EQUATION CONSIDERING NANOGRAIN FORMATION DURING DUCTILE FRACTURE

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Abstract

Ti-6Al-4V titanium alloy is a staple in aerospace, biomedical, and automotive industries, owing to its exceptional strength-to-weight ratio, corrosion resistance, and biocompatibility. However, its ductile fracture behavior under quasi-static tension remains incompletely characterized, particularly regarding the coupling effects of void evolution, stress triaxiality, and nanograin formation. The traditional Gurson-Tvergaard-Needleman (GTN) model, a widely used framework for ductile fracture prediction, primarily focuses on stress triaxiality-driven void nucleation, growth, and coalescence. It fails to account for energy dissipation caused by nanograin formation during local severe-plastic deformation (LSPD), leading to inaccurate predictions for real process of ductile fracture.

This study addresses this limitation by systematically exploring the ductile fracture mechanism of equiaxed Ti-6Al-4V under quasi-static tension. Experimental observations reveal that stress triaxiality directly modulates void behavior: higher stress triaxiality accelerates void expansion and promotes coalescence at the intersections of adjacent voids, forming the ridges of ductile dimples. These dimple ridges serve as hotspots for LSPD, where accumulated plastic strain surpasses the critical threshold for nanograin nucleation. The newly formed nanograins consume additional deformation energy, a phenomenon unaccounted for in the traditional GTN model.

Building on these findings, the study extends the GTN model by integrating the quantified nanograin formation energy as an additional dissipation term into the model's total energy balance. This modification yields a new failure evolution equation that retains the GTN core (stress triaxiality-dependent void evolution) while coupling nanograin-induced energy dissipation. Validation against quasi-static tensile tests shows the extended model accurately predicts Ti-6Al-4V's stress-strain response, fracture strain, and fracture surface morphology (including dimple size and nanograin distribution) - outperforming the traditional GTN model, which underestimates energy consumption and overpredicts fracture toughness. This work enhances the theoretical basis for Ti-6Al-4V's fracture prediction and provides a scalable approach for modeling ductile fracture in other metals susceptible to nanograin formation during LSPD.

Keywords: ductile fracture; nanograins; voids; stress triaxiality; Gurson-Tvergaard-Needleman (GTN) model

THE ROLE OF DISLOCATION CLIMB AND GLIDE DURING CREEP

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Abstract

Creep deformation takes place by climb and glide of dislocations. Already during the 1950ties, Weertman proposed that glide would be rate controlling if the stress exponent for the creep rate was about 3 and climb controlling for a stress exponent of about 5. For some binary solid solution alloys, the stress exponent is 3 in certain temperature and stress intervals, which has almost consistently been considered as evidence of glide control. Such alloys are referred to as class A alloys. Commonly studied alloys are Al-Mg and Al-Zn. For most metals and other alloys the stress exponent is higher (class M alloys).

However, the assumption of glide control can be questioned. During stationary creep there must be a balance between work hardening and static recovery. Otherwise a constant strain rate cannot be obtained. For climb there is a well-established recovery process but not for glide. The only plausible mechanism that provide static recovery for glide is cross-slip, where dislocations on one glide plane can move to another one. However, cross-slip only works for screw dislocations and the activation energy for cross-slip is typically considerably lower than that observed for creep.

Class A alloys have traditionally been modelled by assuming a transition from climb to glide control and then back to climb control again with increasing stress, which is difficult to justify. In fact, it can be shown that a climb based model can fully describe the stress dependence. This is illustrated in Figure 1 for Al-Mg alloys.

It can be concluded that stationary creep requires climb control and that climb based models can handle also the class A alloys. Prediction of creep life should involve climb based models. Such models are readily available and they can cope also with extensive extrapolation.

Keywords: Dislocation creep; Climb; Glide; Class A alloys; Solid solution

Reference

- [1] R. Sandström, Analysis of creep in class A alloys with dislocation climb based models, Mater High Temp, (2025) 1-11, DOI 10.1080/09603409.2025.2571840

TRANSFERABILITY OF FRACTURE TOUGHNESS FOR DIFFERENT SPECIMENS USING A CONSTRAINT-BASED APPROACH

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Abstract

The fracture toughness of a material in the ductile-to-brittle transition temperature range (DBTT) is typically determined through fracture toughness tests on compact tension (CT) specimens and single edge notched bend (SENB) specimens. Given the challenges of testing large-scale cracked components, fracture toughness data obtained from laboratory specimens are widely used to assess the structural integrity of cracked components. However, fracture toughness varies significantly with specimen size attributed to the difference in crack tip constraint. Thus, directly using the fracture toughness of laboratory specimens may lead to an unreliable assessment for the cracked components. To overcome this limitation, it is essential to develop a constraint-based approach to transfer fracture toughness for different sized specimens.

In this study, fracture toughness tests were conducted using CT and SENB specimens fabricated from 0.55% carbon steel. Charpy impact test was performed to determine the DBTT for the steel, and based on test results, room temperature was selected as the fracture toughness test temperature. For both CT and SENB specimens, a specimen width W of 25 mm and two thickness-to-width ratios with $B/W = 0.25$ and 0.5 were considered. Additionally, fatigue pre-cracking was conducted for each specimen to maintain the crack length-to-width ratio a/W within the range of 0.49 to 0.51 . From the tests, fracture toughness data J_c were obtained for CT and SENB specimens with the data validity confirmed through ASTM E1921. Next, three-dimensional finite element analyses (FEAs) were performed on the tested CT and SENB specimens to calculate the in-plane and out-of-plane constraint parameters T_{11} and T_{33} , respectively. Based on both experimental and numerical results, a three-parameter constraint-based approach, i.e., J_c - T_{11} - T_{33} , was developed. The proposed constraint-based approach was applied to predict fracture toughness for other sized CT specimens (i.e., $B/W = 1.0$ and $a/W = 0.5$) and SENB specimens (i.e., $B/W = 1.0$ and 1.5 , $a/W = 0.5$) made of 0.55% carbon steel. By comparing the predicted values with experimental J_c results, it is found that their maximum difference is less than 13%, demonstrating the applicability of our proposed approach for transferring fracture toughness among different specimens. This finding provides empirical evidence supporting the transferability of fracture toughness from small-scale laboratory specimens to large-scale cracked components.

Keywords: Fracture toughness; Crack tip constraint; Ductile-to-brittle transition temperature range; J_c - T_{11} - T_{33} , Specimen size effect

SHEAR FORCE IN AN INTERNAL FRAME CONNECTION FROM A BEAM UNDER SYMMETRICAL LINEARLY DISTRIBUTED LOAD WITH INTENSITY AT THE END SECTIONS – SYMMETRICAL CROSS SECTION

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Abstract

The vulnerability of the beam-column connection to shear force is a cause of failure. Determining shear force is a complex task with many influencing factors. In the current Eurocode 2, the shear force is determined capacitively, based on the area of the inserted longitudinal reinforcement between the beam and the column. However, this does not answer the question of how large forces are transmitted from the beam to the column as a result of the specific load and the geometric and material characteristics of the beam. This article examines a mathematical model of the beam (Figure 1), which allows all these factors to be taken into account. The load is a linearly distributed symmetrical with intensity in the end cross-sections. An analytical solution has been performed and the equations of the support reactions of the beam along the lateral edge in height have been determined. The shear force is calculated with the exact forces determined with the newly derived formulas. To validate the results, a comparison was made of the new shear force with that determined by an approximate method recommended in the literature. The difference is up to 28%. A comparison with the shear force determined according to Eurocode 2 was also made. The result shows a difference of 38%.

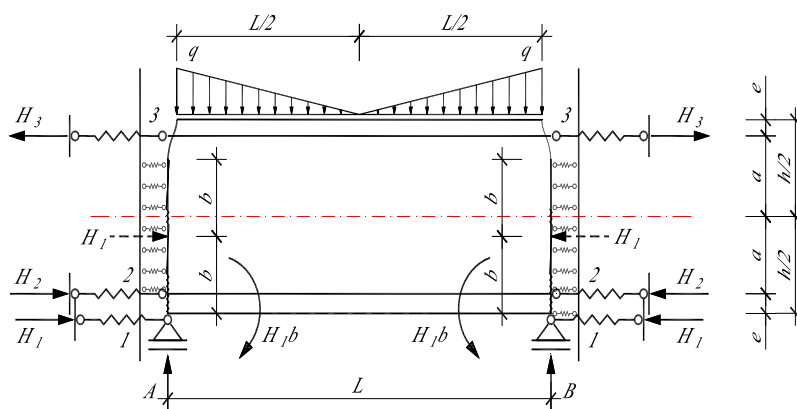


Figure 1. Mathematical model of the beam.

Keywords: larges deformations; crack on the face of the column; analytical simulation; shear force; linearly distributed load

Acknowledgement

Research № BS-328/25 on the Research, Consultancy and Design Centre (RCDC) of the University of Architecture, Civil Engineering and Geodesy (UACEG) - Sofia, funded this study.

SHEAR FORCE IN AN INTERNAL FRAME CONNECTION FROM A BEAM UNDER SYMMETRICAL LINEARLY DISTRIBUTED LOAD WITH INTENSITY AT THE END SECTIONS – ASYMMETRICAL CROSS SECTION

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Abstract

Seismic failures in framed structure buildings are often the result of collapse on the beam-column connection. The resulting shear forces are difficult to determine due to the presence of many influencing factors. In the current Eurocode 2, the shear force is determined capacitively. The actual magnitude of the shear force remains unknown. For its determination, the force transmitted from the beam to the column as a result of a specific load and the geometrical and material characteristics of the beam are required. This paper examines a mathematical model of a beam (Figure 1) that allows all these factors to be taken into account. The load is linearly distributed symmetrically with intensity at the end cross-sections. An analytical solution for an asymmetric cross-section was performed and the equations of the support reactions of the beam along the lateral edge in height were determined. The shear force is calculated with the exact forces determined with the newly derived formulas. To confirm the results, a comparison of the new shear force with that determined by an approximate method recommended in the literature was made. The difference is up to 26%. A comparison was also made with the shear force determined according to Eurocode 2. The result showed a difference of 37%.

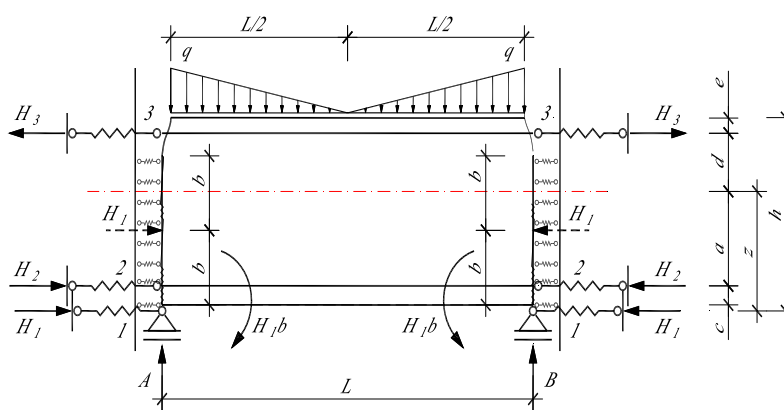


Figure 1. Mathematical model of the beam.

Keywords: large deformations; crack on the face of the column; analytical simulation; shear force; linearly distributed load

Acknowledgement

Research № BS-328/25 on the Research, Consultancy and Design Centre (RCDC) of the University of Architecture, Civil Engineering and Geodesy (UACEG) - Sofia, funded this study.

VARIATION OF SHEAR FORCE BY CANTILEVER BEAM AND LINEARLY DISTRIBUTED LOAD OCCUPYING DIFFERENT POSSIBLE POSITIONS - SYMMETRICAL CROSS SECTION

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Abstract

Shear force occurring during seismic impacts on frame building structures can lead to damage and collapse of buildings. Its determination is a complex task with many influencing factors. In the current Eurocode 2, the shear force is determined capacitively, based on the area of the longitudinal reinforcing bars from the beam entering the beam-column connection. The actual magnitudes of the forces that are transmitted from the beam to the column as a result of the particular loading remain unknown. This paper examines a mathematical model of the beam (Figure 1) that allows the specific loads, geometric and material characteristics of the beam to be taken into account. The load is linearly distributed, occupying different possible positions and with intensity towards the free end of the beam with a symmetric cross-section. An analytical solution was performed and the equations of the support reactions of the beam along the lateral edge in height were determined. The shear force is calculated with the exact forces determined with the newly derived formulas. To confirm the results, a comparison of the new shear force with that determined by an approximate method recommended in the literature was made. The difference is up to 37%. A comparison was also made with the shear force determined according to Eurocode 2. The result showed a difference of 62%.

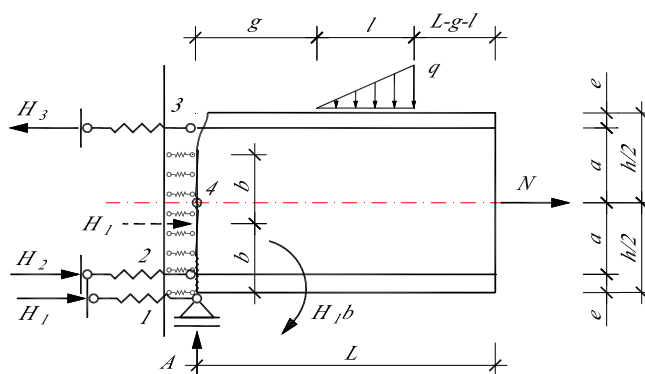


Figure 1. Mathematical model of the beam.

Keywords: large deformations; crack on the face of the column; analytical simulation; shear force; linearly distributed load occupying different possible positions

Acknowledgement

Research № BS-328/25 on the Research, Consultancy and Design Centre (RCDC) of the University of Architecture, Civil Engineering and Geodesy (UACEG) - Sofia, funded this study.

VARIATION OF SHEAR FORCE BY CANTILEVER BEAM AND LINEARLY DISTRIBUTED LOAD OCCUPYING DIFFERENT POSSIBLE POSITIONS - ASYMMETRICAL CROSS SECTION

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Abstract

During earthquakes, large shear forces occur in beam-column connections. They can cause damage and collapse of buildings. Determining shear forces is a complex task with many influencing factors. In the current Eurocode 2, the shear force is defined capacitively. This approach does not make it possible to determine the actual magnitudes of the forces that are transmitted from the beam to the column as a result of the particular load. This paper considers a mathematical model of the beam (Figure 1), which allows to take into account the specific loads, geometrical and material characteristics of the beam. The load is linearly distributed, occupying various possible positions and is with intensity towards the free end of the beam with an asymmetric cross-section. An analytical solution was performed and the equations of the support reactions of the beam along the lateral edge in height were determined. The shear force is calculated with the exact forces determined with the newly derived formulas. A comparison of the new shear force with that determined by an approximate method recommended in the literature was made. The difference is up to 35%. A comparison was also made with the shear force determined according to Eurocode 2. The result showed a difference of 66%.

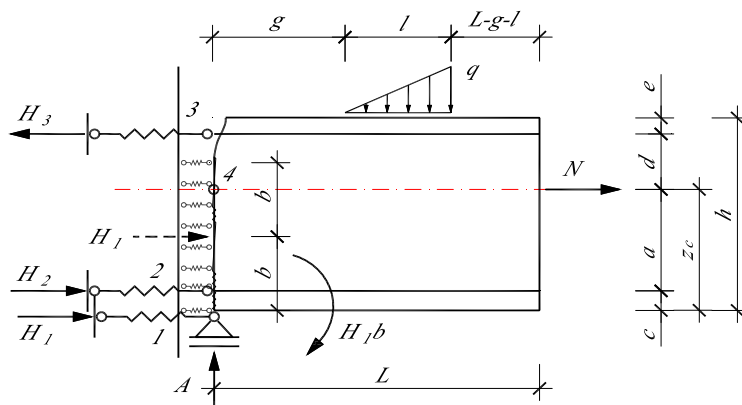


Figure 1. Mathematical model of the beam.

Keywords: large deformations; crack on the face of the column; analytical simulation; shear force; linearly distributed load occupying different possible positions

Acknowledgement

Research № BS-328/25 on the Research, Consultancy and Design Centre (RCDC) of the University of Architecture, Civil Engineering and Geodesy (UACEG) - Sofia, funded this study.

AIRCRAFT MECHANICS AND CONTROL

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- Z. Liu, X. Zheng, Y. Chen, T. Deng - *Assessing the effect of delamination damage on the residual compressive strength of aircraft composite laminates*
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PASSIVE DAMPING OF PRESTRESSED PLATES AND SHELLS USING PIEZOELECTRIC ELEMENTS

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Abstract

The continuous pursuit of reducing the weight of civil aircraft and sports cars increases the sensitivity of structures to vibration and resonance. Thin plates and shells are particularly prone to these phenomena due to their low rigidity and damping. Under real-life operating conditions, they are subject to various forces that significantly affect their dynamic behaviour.

This study investigates the influence of static pressure on the efficiency of passive damping of the first vibration mode of a rectangular plate and a circular cylindrical shell using a piezoelectric element connected to an external electrical circuit. Its parameters, which guarantee the highest rate of free vibration damping, are determined from the solution of the optimization problem. Two types of electrical circuits are considered in the examples. The first consists of a single resistor and is analogous to viscous damping. The second one is a resonant RL-shunt (resistor and inductor connected in series). The results of finite element modelling made it possible to evaluate the performance of passive vibration damping technique depending on the value of static load. Typical dependencies of natural frequencies and damping ratio are shown in Figure 1 for the rectangular plate rigidly clamped at all edges. The results obtained allow us to conclude that static loading finally has a negative effect on the passive vibration damping.

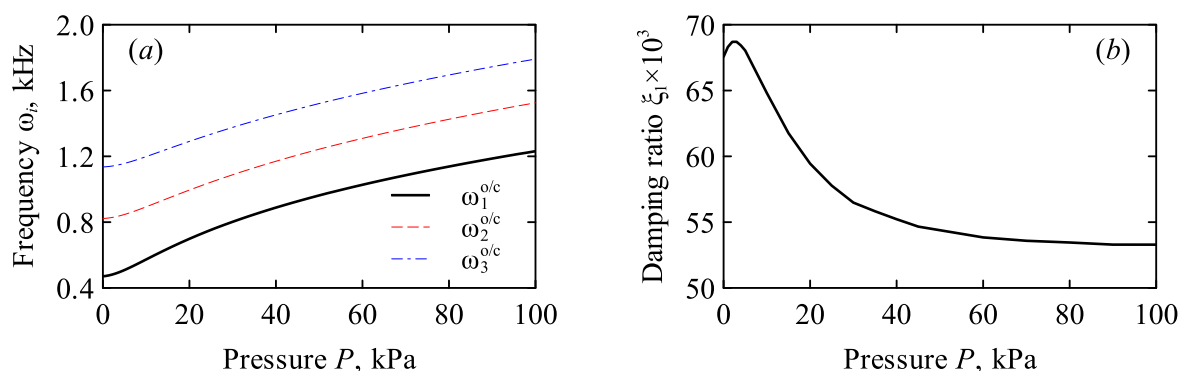


Figure 1. Dependence of the natural frequencies (a) and damping ratio (b) of the plate on pressure (RL-circuit)

Keywords: Passive damping; shunted piezoelectric elements; prestress; shells; plates, finite element method.

Acknowledgement

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ASSESSING THE EFFECT OF DELAMINATION DAMAGE ON THE RESIDUAL COMPRESSIVE STRENGTH OF AIRCRAFT COMPOSITE LAMINATES

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Abstract

The incorporation of damage tolerance design is imperative to guarantee the structural integrity of aircraft composite components. For aircraft composite laminates, delamination damage is easy to occur in the manufacture and use. The existence of delamination damage will significantly reduce the strength, stiffness and stability of the structure, resulting in early instability and overall failure of the structure. Therefore, it is necessary to explore the influence of delamination damage on the mechanical properties of composite laminates. It needs to be solved urgently that how to select materials for easy delamination parts of composite structures. The analysis of the influence of delamination depth on the mechanical properties of composite structures needs to be improved. Therefore, four kinds of carbon fiber reinforced epoxy resin matrix composites were selected for single delamination damage and impact damage. Quasi-static compression, low-velocity impact and compression after impact tests were carried out to compare the compressive residual strength of four composite laminates with delamination damage. Combined with finite element simulation, the influence trend of delamination depth on the compression performance of composite laminates is explored, and the reasons for this trend are analyzed. The results demonstrate that the use of high-strength fabric prepreg is preferred in delamination-prone areas of composite structures, owing to its greater resistance to delamination compared to unidirectional prepreg. In addition, the bearing capacity of composite laminates is governed by different sub-laminate configurations, depending on the depth of the delamination. This study thoroughly investigates the influence of delamination damage on the compressive properties of aircraft composite laminates, which serves as a critical foundation for advancing damage tolerance design and ensuring structural integrity.

Keywords: Aircraft composite structures; Laminates; Delamination damage; Residual compressive strength; Delamination location

Acknowledgement

This work was supported by the National Key R&D Program of China (2023YFB3709603) and Aeronautical Science Foundation of China (ASFC-20230015053005).

VALIDATION OF A NUMERICAL MODEL FOR THE ILSS PREDICTION IN GLARE

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Abstract

Fibre Metal Laminates (FMLs), particularly the Glass Laminate Aluminium Reinforced (GLARE), represent a critical class of advanced hybrid materials in the aerospace sector, prized for their ability to combine the most desirable properties of metals and fibre-reinforced composites. This synergy yields materials with exceptional damage tolerance and fatigue resistance, overcoming the inherent limitations of their monolithic constituents. However, their layered architecture introduces a specific vulnerability: delamination, which is primarily driven by interlaminar shear stresses. The characterisation of the Interlaminar Shear Strength (ILSS) is therefore an essential parameter for the design and structural integrity assessment of FML components. While experimental testing is indispensable, it is also a costly and time-consuming process. This reality motivates the development of reliable numerical models that can function as "virtual testing" platforms to predict material behaviour. This work presents a rigorous validation of a finite element model (FEM) for forecasting the interlaminar shear response of a GLARE laminate.

The methodology employed a dual approach, combining a physical experimental campaign with a high-fidelity numerical simulation. Experimentally, ILSS tests were performed on GLARE specimens according to established standards. In parallel, a three-dimensional FEM was developed, precisely replicating the geometry and boundary conditions of the experimental setup. The aluminium layers were modelled with an elastic-plastic behaviour, while the composite layers were defined as orthotropic. The most crucial aspect of the model was the implementation of an advanced interface model at the aluminium-composite boundary.

The comparison between the experimental data and the numerical predictions revealed an exceptional agreement. The simulated load-displacement curves almost perfectly matched the experimental ones, accurately capturing the initial stiffness and the peak load. The ILSS value calculated from the simulation differed less than 7% from the experimental average, confirming the model's quantitative accuracy. Beyond this numerical concordance, the model also qualitatively predicted the failure mechanism. The simulation showed damage initiating and propagating along the laminate mid-plane, perfectly replicating the horizontal delamination crack observed in the physically tested specimens.

Keywords: Advanced Hybrid Material; Fibre Metal Laminates; Numerical Simulation; ILSS

STRAIN MONITORING OF HELICOPTER LANDING GEAR USING FBGS DURING FLIGHT OPERATIONS

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Abstract

The present study presents the findings of an experimental investigation into the strain response of the main landing gear of a rotary-wing aircraft instrumented with fiber Bragg gratings (FBG). As illustrated in Fig. 1a, four FBGs (labeled S1, S2, S3 and S4) were mounted in accordance with the configuration, thereby facilitating distributed monitoring of structural deformation during both ground and flight operations. The rotary-wing aircraft used for the test is the Erickson (Sikorsky) S-64 Skycrane belonging to the Italian National Fire Brigade Corps, officially called the "Corpo Nazionale dei Vigili del Fuoco" (CNVVF), which is the Italian government's agency responsible for fire and rescue services.

The focus of this study is the strain behavior observed during repeated landing phases involving touch-and-go maneuvers. An example is shown in Fig. 1b. The data acquisition process was executed utilizing an Aerogator system, operating at a sampling rate of 1.0 kHz. This configuration facilitated the acquisition of high-resolution transient events. The time-domain strain profiles manifest distinct signatures corresponding to rotor-induced lift asymmetries and wheel contact sequences. Frequency-domain analysis conducted via the Fast Fourier Transform (FFT) further identified dominant modal frequencies in the range of 9–500 Hz, associated with landing gear dynamics and rotor-structure interactions. The findings emphasize the efficacy of fiber Bragg grating (FBG) technology in facilitating in-situ structural health monitoring of helicopter landing gear under authentic operational conditions. The technology exhibits superior sensitivity, temporal resolution and durability in intricate dynamic environments.

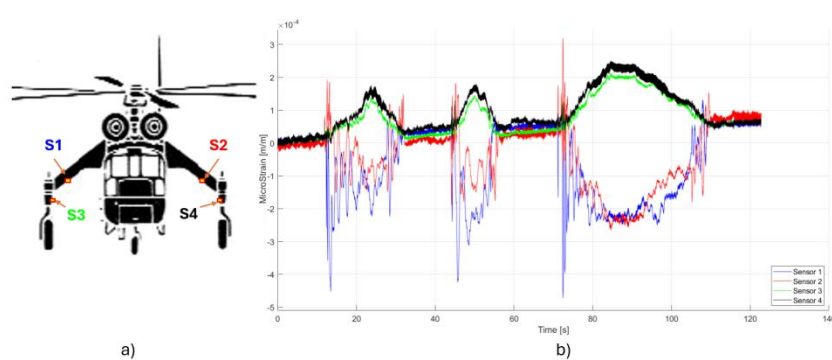


Figure 1. a) FBGs' array arrangement; b) an example of strain behavior recorded by the FBGs' sensing array

Keywords: Smart Landing Gear; Weight on Wheel; Integrated Sensor Network; Strain Detection; Fiber Bragg Gratings (FBG);

INVESTIGATION OF EROSION–MECHANICAL LOAD COUPLING BEHAVIOR OF AEROENGINE BLADE

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Abstract

Aeroengine blades operate under complex stress states induced by high-frequency vibrations. Changes in stress conditions can intensify erosion damage, further reducing component service life. However, the interaction mechanisms between alternating mechanical stress and erosion remain unclear, and current models fail to quantify the influence of stress on gas–solid erosion behavior. In this study, the erosion behavior of additively manufactured TiB₂/Al–Si composites under different loading conditions, as well as the effect of erosion-induced damage on fatigue life, were experimentally investigated. Results reveal that axial static loads below the yield point lead to increased erosion rates at all impact angles. Erosion-induced defects and inherent manufacturing defects compete to dominate fatigue failure. Furthermore, fluid–structure interaction simulations show that higher erosion angles concentrate impact areas and amplify local surface pressures, accelerating damage accumulation. To quantify the influence of stress states on the erosion process, a modified Tabakoff–Grant erosion model incorporating yield strength, Mises stress, and crater volume was developed, and implemented in MATLAB. Additionally, a fatigue–erosion life model was proposed, using a weight function to dynamically switch between dominant defect types. This work provides theoretical support for evaluating damage tolerance of aeroengine blades under complex service conditions and offers a reliable approach to predict erosion rates under static loading.

Keywords: Erosion-fatigue test; Erosion-tension coupling; Erosion rate prediction; Modeling

Acknowledgement

This work was sponsored by the National Natural Science Foundation of China (52222505 and 52321002) and Natural Science Foundation of Shanghai (23ZR1415500).

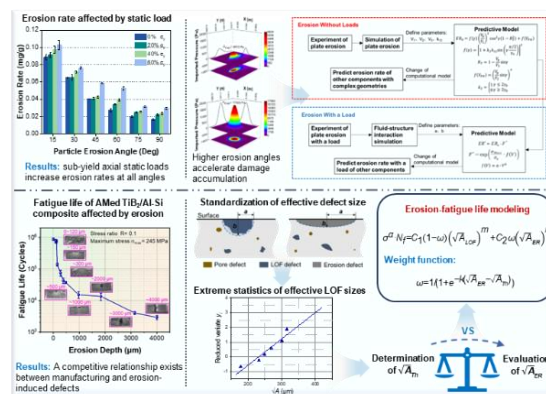


Figure 1. Graphical abstracts

A UNIFIED IMPLICIT FINITE VOLUME METHOD FRAMEWORK FOR CONJUGATE HEAT TRANSFER ON UNSTRUCTURED MESHES

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Abstract

This paper presents a computational framework based on the implicit finite volume method for solving the Navier-Stokes equations in the fluid domain and the heat conduction equation in the solid domain. By enabling information exchange across the coupling interface, the framework achieves conjugate heat transfer (CHT) simulation. The governing equation for heat conduction is first discretized using the finite volume method, resulting in a formulation that is consistent with the Navier-Stokes equations. A unified numerical approach is then employed for both the fluid and solid domains, incorporating the GMRES linear solver, exact Jacobian matrix computation, and adaptive time step. Numerical results demonstrate that this methodology enhances both the stability and computational efficiency of the fluid flow and solid heat conduction simulations. Furthermore, a novel interpolation method for non-matching interfaces is developed. This method utilizes a polygon clipping algorithm combined with an area-weighted interpolation scheme to facilitate data transfer at the coupling boundary, thereby enabling robust CHT simulations. Computational results confirm that the proposed approach achieves high accuracy in conjugate heat transfer applications.

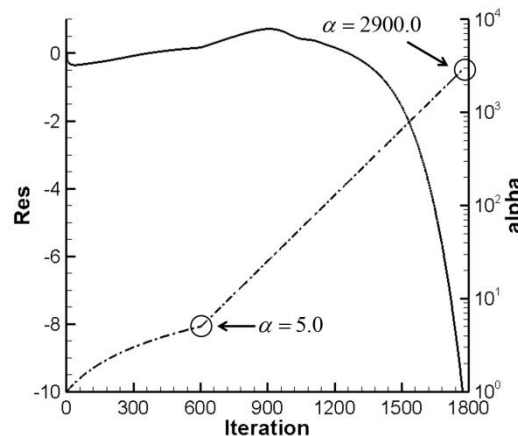


Figure 1. The convergence history of density and the increasing history of the time step amplification factor α for a flow past a cylinder at $Ma = 2.0$ and $Re = 300$.

Keywords: finite volume method; exact Jacobian matrix; adaptive time step; non-matching interface; conjugate heat transfer

ASSESSMENT OF CARBON-GLASS HYBRID COMPOSITES FOR HELICOPTER BLADES DESIGN

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Abstract

Helicopter blades are manufactured from hybrid carbon and glass fiber composites. When designing helicopter blades, careful consideration must be given to potential failure modes, especially those associated with crack initiation and propagation. This study aims to generate dataset that will be used for (i) XFEM simulation; and (ii) machine learning models. The hybrid composite structure consisted of a four-layer unidirectional symmetric laminate. It was produced using the vacuum bag resin transfer molding technique. Experimental specimens were subjected to a series of tests: (1) a dynamic mechanical analysis (DMA) test was performed; (2) a differential scanning calorimetry (DSC) test; (3) a multi-impact fatigue test; (4) a Critical impact force test under low velocity; (5) and the crack propagation growth of the hybrid composite is evaluated according to ASTM D5528-01 standard, using a double cantilever beam (DCB) test. Based on the experimental results, the mechanical and thermal properties of the hybrid composite is then compared with various hybrid configuration. The findings provide valuable data for comparison of crack propagation growth using XFEM and machine learning models.

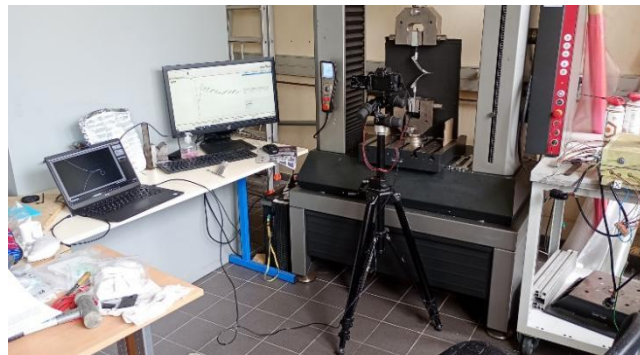


Figure 1. Delamination test on carbon/glass/glass/carbon hybrid composites

Keywords: Aircraft fairing; helicopter blades; Critical impact force; Loss modulus; Energy absorbed

MACHINE LEARNING-BASED INVERSE METHOD FOR DETERMINING ELASTIC COEFFICIENTS OF UNSYMMETRIC LAMINATES

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Abstract

The design and deployment of high-performance composite structures in unmanned aerial vehicles (UAVs) demand precise control over elastic behavior, particularly in unsymmetric laminates that enable tailored aeroelastic responses such as passive load alleviation or morphing capabilities. However, the accurate determination of elastic coefficients in such laminates remains challenging due to inherent bending–twisting and extension–shear couplings that invalidate classical laminate assumptions. To address this gap, this work introduces an integrated computational framework that combines a machine learning–based inverse identification method with a purpose-built laminate design optimizer, both developed to engineering readiness for application in UAV structural development.

The inverse characterization module employs supervised regression models—including random forest, support vector regression, and gradient-boosted decision trees—to predict the full set of effective elastic constants (including in-plane shear modulus G_{12}) directly from global structural responses. To ensure physical consistency and traceability to established practices, standardized ASTM test methods were virtually adapted for unsymmetric configurations: tensile characterization followed a modified ASTM D3039 protocol, while the in-plane shear modulus was determined using a finite element implementation of the ASTM D7078/D7078M V-notched rail shear test. High-fidelity simulations were performed in FEMAP with Nastran, accounting for realistic boundary conditions, lay-up asymmetry, and material heterogeneity. The resulting dataset maps simulated displacement fields, reaction forces, and strain distributions to corresponding stiffness coefficients, enabling regression models that achieve high predictive accuracy ($R^2 > 0.9$) and robust generalization across diverse fiber architectures.

Complementing this, a bespoke software tool was developed and matured to engineering readiness, operating in the inverse design direction: for a given set of target elastic properties—such as tailored coupling stiffnesses required for aeroelastic tailoring in UAV wings—the software autonomously generates manufacturable, optimal fiber orientations and stacking sequences. The optimizer respects practical constraints including ply contiguity, maximum off-axis angles, balance requirements, and compatibility with automated fiber placement (AFP) processes. This closed-loop system bridges material characterization and structural design, enabling rapid “property-to-layup” synthesis without iterative finite element re-analysis.

The entire pipeline has been validated and deployed in the design of UAV wing skins, spars, and control surface components, where precise control over torsional stiffness and twist-coupled bending is critical for flight stability, maneuverability, and weight efficiency. By unifying modified standardized testing, data-driven inverse modeling, and inverse design automation, this framework significantly accelerates the development cycle for advanced unsymmetric composite structures, offering a scalable, physics-informed solution for next-generation UAV and aerospace applications.

The process of dataset generation is illustrated in Figure 1, outlining the workflow from virtual ASTM-based finite element simulations to the extraction of elastic coefficients used for training the regression models.

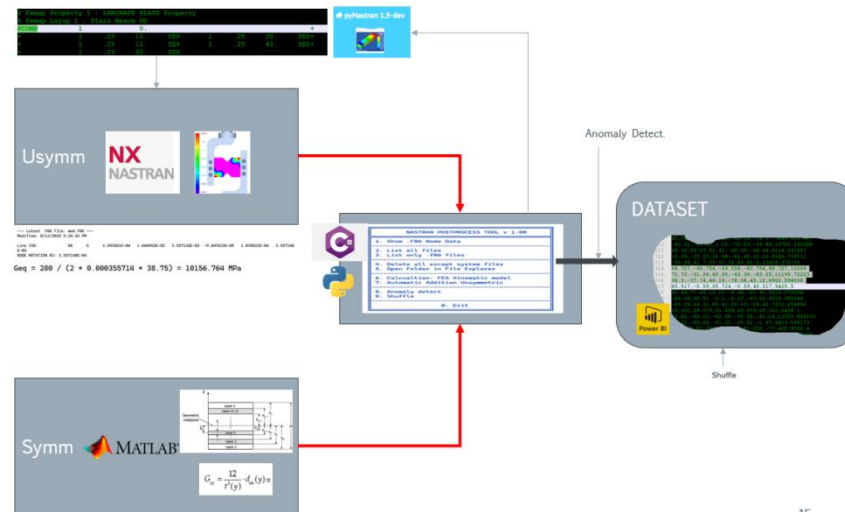


Figure 1. process of dataset generation

Keywords: Machine learning inverse modeling; Composite laminate design optimization; Unsymmetric laminates

A MULTI-PHYSICS ANALYSIS FOR PRESSURE-INDUCED DEFORMATION IN FUSED FILAMENT FABRICATION

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Abstract

Fused filament fabrication (FFF) is a widely adopted additive manufacturing technology, yet the development of manufacturing deformation and interlayer adhesion remain critical challenges governing the mechanical integrity of printed parts. In this investigation, a non-isothermal computational fluid dynamics (CFD) model was developed, incorporating the non-Newtonian rheological behavior of molten thermoplastic materials during the fused filament fabrication process. The CFD simulations demonstrated remarkable accuracy in predicting printing pressure, which were validated through real-time measurements of printing forces using a high-precision force monitoring system integrated into the build platform. Quantitative analysis revealed that the generation of printing pressure is predominantly governed by two mechanisms: (i) the compressive forces induced by the nozzle head on newly extruded thermoplastic materials, and (ii) the impact forces resulting from the deceleration of molten thermoplastic deposition onto the build platform or previously deposited layers. Building upon this foundation, a finite element analysis framework was developed to systematically simulate the layer-by-layer deposition behavior in the FFF process. The model incorporates the thermo-mechanical coupling effects during printing, the orthotropic characteristics of the material, and its viscoelastic constitutive relationship. Innovatively, a dynamic loading mechanism for printing pressure was introduced based on real-time path information to more accurately capture mechanical disturbances in actual printing operations. The results demonstrate that printing speed is the dominant factor governing manufacturing accuracy, where high-speed printing exacerbates heat accumulation and printing pressure, thereby leading to increased deformation. This work provides valuable insights into the mechanisms of pressure-induced manufacturing deformation and establishes a basis for optimizing FFF process parameters to achieve superior structural performance.

Keywords: 3D printing; printing pressure; computational fluid dynamics (CFD); thermo-mechanical coupling

Acknowledgement

The authors would like to acknowledge the financial support from the National Nature Science Foundation of China (grant number: 12132011), and the National Key Research and Development Plan, PR China (grant number: 2022YFB4602000).

PROCESS-DEPENDENT MULTISCALE MODELING FOR 3D PRINTING OF CONTINUOUS FIBER-REINFORCED COMPOSITES

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Abstract

3D-printed continuous fiber-reinforced composites (CFRCs) have significant potential for applications in the aerospace and automotive industries. However, their mechanical performance is often compromised by defects such as interlayer voids, weak interfaces, and insufficient impregnation arising from the layer-by-layer printing process. In this study, we propose a pressure modulation approach to enhance the mechanical properties of 3D printed CFRCs. The pressure-driven intimate contact and impregnation behavior during printing were modeled to reveal the relationship between the printing pressure and the defects. Then, a multi-scale finite element model was developed to link these defects to mechanical performance. Furthermore, we optimized the printing pressure by adjusting the printing layer height, which significantly reduced defects and led to a nine-fold increase in the transverse tensile strength of 3D-printed CFRCs. The experimental results of CFRCs printed at different layer heights validate the proposed model, demonstrating that increasing printing pressure enhances intimate contact and impregnation, hence improving the mechanical performance of 3D-printed CFRCs. This study proposes a pressure modulation approach to enhance the mechanical performance of 3D-printed CFRCs, enabling their broader application in the aerospace and automotive industries.

Keywords: 3D printing; Multiscale modeling; Continuous fiber-reinforced thermoplastic composites; Tensile strength; Manufacturing defects

HYGROTHERMAL STRESS ANALYSIS OF HYBRID POLYMER COMPOSITE LAMINATES

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Abstract

Polymer matrix composites are particularly suited for aerospace and aeronautical applications owing to their exceptional strength-to-weight ratios. During operational service, these materials encounter fluctuating and severe environmental conditions, including temperature variations and moisture exposure. Such hygrothermal conditions induce residual stresses within composite structures, necessitating careful consideration during the design and sizing of components intended for humid environments.

This study investigates the hygrothermal response of hybrid composites, with a focus on stress distribution and aging effects. The mechanical properties of aged composites are assessed based on temperature, moisture concentration profiles, and exposure duration under varying environmental conditions. The analysis employs the Tsai transient aging model, originally developed to examine composite behavior during moisture absorption.

Furthermore, the research explores the hybrid composite effect by simulating a structure composed of two distinct composite materials. By varying the thickness of the outer layer, the study evaluates its impact on the performance of inner layers. The findings highlight the critical role of hygrothermal properties in shielding inner layers from moisture infiltration, ensuring long-term structural integrity.

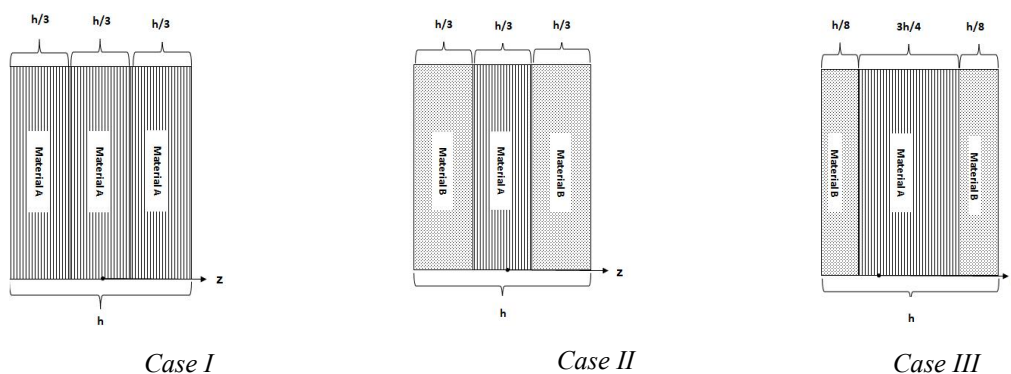


Figure 1. Simple and hybrid laminates.

Keywords: Hybrid composite; Hygrothermal stress; Aging composite

MODELING STIFFNESS REDUCTION IN Al/Al₂O₃ COMPOSITES: THERMO-MECHANICAL INTERACTION OF PORES AND MICROCRACKS

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Abstract

The present research investigates the thermo-mechanical degradation of Al/Al₂O₃ composites, focusing on the combined effects of porosity and crack damage on Young's and shear moduli. While existing models primarily consider porosity, this work integrates both porosity and microcrack evolution, providing a more comprehensive understanding of stiffness reduction under thermo-mechanical loading. A predictive model is developed to assess the impact of temperature, alumina volume fraction, and microstructural defects on modulus degradation. The results highlight the significant role of thermal expansion mismatch in inducing stress concentrations, leading to crack propagation and interface debonding, particularly at higher temperatures. Unlike previous models that consider only porosity effects, this study integrates both porosity and microcrack evolution. The model's accuracy is validated against experimental data and finite element simulations, demonstrating superior predictive capability. These findings provide a robust framework for optimizing metal-ceramic composites in aerospace and high-temperature structural applications where mechanical integrity under thermal stress is critical.

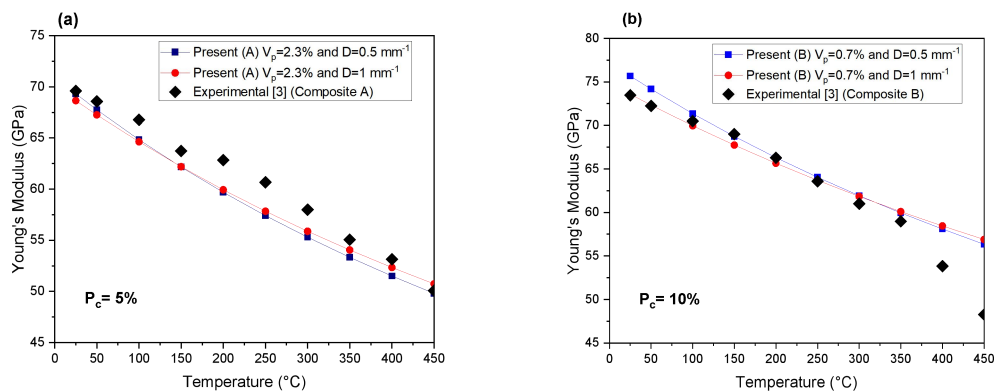


Figure 1. Young's modulus degradation of Al/Al₂O₃ composites at different alumina volume contents and temperatures ((a) Composite A :V_p=2.3% and CTE_{Al}=28.02 μm/m°C ; (b) Composite B :V_p=0.7% and CTE_{Al}=26.1 μm/m°C)

Keywords: Crack damage; Metal/ceramic composite; Porosity; Thermo-mechanical loading; Young's modulus.



SPONSOR DETAILS

This section of the Book of Abstracts is dedicated to detailed information about our sponsors, their history and activities. The Organizing Committee of the *First Biennial ESIS-CSIC Conference on Structural Integrity* - BECCSI 2025 would like to take this opportunity to once again express our gratitude to the sponsors, and their efforts and support in organizing of our conference!

Special gratitude goes out to the **Ministry of Science, Technological Development and Innovation** of Republic of Serbia for providing continued support to our efforts in organising conferences and scientific work in general, and their substantial financial aid.



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About the company

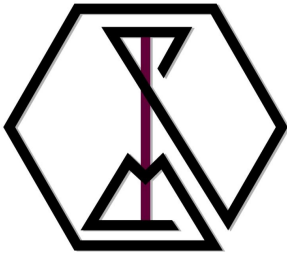
MONT-R, with two decades of history, from its establishment in 2003 until today, has become one of the leading contractor in Serbia, which is constantly present at European market (Germany, Slovenia, Macedonia, Bosnia and Herzegovina) in the field of mechanical works, engineering and production of pipelines, steel structures and equipment under pressure. Our diverse portfolio includes: production, assembly, overhaul, current and intervention maintenance of the most complex and strategically important industrial plants, thermal power plants, refineries, petrochemical plants and metallurgical complexes.

The company has more than 300 employees, who are qualified and competent to perform the tasks they are assigned to. The continuous work of the collective, which is supported by the implemented standards of the quality management system (ISO 9001, ISO 14001, 45001) along with various other standards (EN ISO 3834-2, EN ISO 17663, EN ISO 17025, etc.), with the possession of various personal specializations and professional knowledge of 25 engineers and technicians is the basis for the initiation of all projects, their planning and implementation. A complete team of employees are assigned to jobs such as: site engineers, assembly and welding planning, occupational safety and health engineers, assembly and welding supervisors, QA & QC Management, locksmiths and welders.

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About the company

Sanacija i ispitivanje metala ltd is a private company founded in 2018, and its main activity is non-destructive testing of metals and the repair of turbines and hydro-mechanical equipment in hydropowerplants.

The CEO of ***Sanacija i ispitivanje metala ltd*** is Milan Miladinov, Msc. Of Mechanical Engineering. Our company maintains a presence in the regional electric industry (EPS-Beograd, MH Elektroprivreda Republike Srpske a.d. – Trebinje, EPCG A.D. – Nikšić, Crna Gora, AD ESM – Skoplje – S.Makedonija, JP Elektroprivreda HZHB d.d. – Mostar, JP Elektroprivreda BiH d.d. Sarajevo. The company possesses the technology and extensive experience in repairing of all three types of turbines - Francis, Pelton and Kaplan). In addition to cavitation rehabilitation, we have been entrusted with rehabilitation of cracks in all three types of turbines in major hydroelectric power plants. Cracks are repaired according to the turnkey system, in accordance with our own repair technologies.

Without false modesty, not a lot of companies can say this about themselves, including companies from outside of our region. We are also experienced in defining the technical conditions for revitalisation of hydropowerplants, receiving of equipment during modernisation of hydropowerplants in LMZ factory - Sankt Petersburg, Russia, ANDRIZ - Ravensburg, Germany, VOITH - St. Polten, Austria, Litostroj - Ljubljana, Slovenia, etc.

Sanacija i ispitivanje metala ltd is a quite successful in solving of technical issues involving machines and equipment in hydropower plants and other industrial facilities.

Sanacija i ispitivanje metala ltd has a well-established cooperation with the IMS institute from Belgrade, Electro-technical institute Nikola Tesla (Belgrade), Mihajlo Pupin institute (Belgrade), TERMOOPREMA ltd (Belgrade), ATB FOD ltd (Bor), ATB North ltd (Subotica) and many others.



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About the company

Veritas Integrity company mainly deals with activities related to testing and conformity assessment of pressure equipment. These activities include, among others:

- Inspection of pressure equipment
- Conformity assessment and certification of pressure equipment in accordance with PED, API and ASME BPVC
- Trainings for inspectors and QMS in Oil&Gas
- Development and sales of software for design of pressure equipment PV Calc in accordance with EN 13445

Employed engineers have licenses of responsible institutions and responsible contractors, certificates, and completed courses in certain areas that are the subject of our business. The key is commitment, a sense of belonging to the team, initiative, and the pursuit of constant progress and learning which is the most effective way of career development. With our training plans, we aim to provide our employees with training and high qualifications in accordance with the relevant domestic and international standards. The training plan is not only designed to meet the needs of business processes but also to contribute to the development of the quality system we strive for and want to develop. Constant supervision and monitoring of work results enable employees to have a good insight into their work and to direct their activities in the right way in order to achieve better results and constant career advancement.

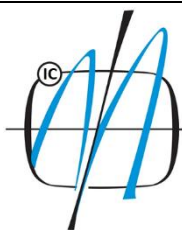


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About the Faculty

Faculty of Mechanical Engineering, University of Belgrade is an institution of national importance and is the basis for the development of mechanical science and industry in Serbia. The oldest and largest educational and scientific institution in the country in the field of mechanical engineering. Faculty of Mechanical Engineering, University of Belgrade, performs basic, applied, and scientific research to improve education research in the areas of production engineering and computers applications, machinery (transport, construction and mining machinery), agricultural mechanical engineering, motor vehicles and trailers (transport, labor and special) effectiveness of mechanical systems, thermodynamics, thermal power, hydropower, railway engineering, shipbuilding, aviation, military mechanical engineering, weapons systems, and cosmic technology, process technology, automated management, plant design and factory plants, warehouses, transportation and process systems, industrial engineering, management, bioengineering, biomedical engineering, nanotechnology, food engineering, applied mechanics, applied fluid mechanics, theory of mechanisms and machines, general machine construction, combustion, applied theory of elasticity, feed materials, mechanical materials, tribology, welding, machine elements and design, applied mathematics, physics, electrical engineering, automatic processing data, labour and environment.

Faculty of Mechanical Engineering also participates in organizing of scientific conferences and seminars, cooperation with educational, scientific and other organizations at home and abroad. Our institution is also involved in performing teaching educational and research activities aimed at improving science and collaboration with industry and other organizations to solve basic, applied scientific problems, studies, expertise etc.



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About the organization

The Innovation Center of the Faculty of Mechanical Engineering in Belgrade is an organization that applies its own and others' scientific results and modern technological processes in an original and systematic way in order to improve existing or create new products, processes and services. The activities of the Innovation Center so far include the implementation of various projects, as well as consulting work related to quality control, expert processes, product certification, etc. In further work, we count on the constant improvement of all existing teams and the acquisition of new equipment, which will enable further development of laboratory centers, which opens up opportunities for the expansion of all forms of cooperation, as well as participation in national development projects and programs of international cooperation.

In accordance with modern requirements, with top-notch professional staff, appropriate space, equipment, internet communication, laboratories and other resources necessary for the implementation of programs and projects are provided. The Innovation Center has adequate equipment for scientific and research work and solving specific development problems of various economic activities and organizations, primarily in the following areas:

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- Information technologies
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The Innovation Center is the partner of choice for many of the world's leading companies, small and medium-sized enterprises that are looking for technological challenges. We help businesses raise their value through custom development, design, QA and consulting services.



ISPITIVANJE BEZ RAZARANJA
NONDESTRUCTIVE TESTING

📍 Prištinska 10, Niš, Serbia

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About the company

Laboratory DGNDT DOO has implemented the ISO 9001 Quality Management System issued by the internationally recognized certification body Bureau Veritas: Provision of non-destructive testing (NOT testing) services, professional supervision of welding, supervision of the implementation of welding test procedures, supervision of personnel performing NOT testing, preparation of welding technologies (WPQR and WPS lists) and qualification of welding technologies.

We would like to offer you cooperation in the field of Non-Destructive Testing (NDT). The following methods are currently available.

- VT Visual testing,
- UT Ultrasonic testing,
- MT Magnetic particle testing,
- PT Penetrant testing,
- UTT Ultrasonic thickness measurement,
- Supervision of staff for methods RT, UT, VT, PT, MT by 3 levels
- Professional supervision over the execution of works (engagement of IWE, IWI-c engineers and NDT level 3 experts)
- RT Radiographic testing (laboratories with which we cooperate).

Repair center:

- Preparation of the necessary documentation (qualification of welding technology WPQR, WPS,...) and repair welding (all methods) and testing of the same, with the preparation of the Study as needed.



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About the institute

The basic idea when establishing the **IMS Institute** was the need for a unique institution, which, in addition to research and development, would deal with regular control of raw materials, semi-finished products and products of the construction and metal industry.

Today, the IMS Institute participates in almost all significant construction projects in Serbia, in the design, control, testing and supervision phase, as well as in work on condition assessment and revitalization of hydro and thermal energy plants.

The strength of the **IMS Institute** is not only in its numerous laboratories, but also in the various specialist services it provides, such as its own construction technology solutions and prestressing systems. With its multidisciplinary, the institute has been a reference institution for all areas of construction and the building materials industry since its foundation until today.

A decades-long tradition of professional activity in the mentioned areas, a series of completed buildings in the country and abroad, the most modern equipment and specialized highly skilled staff, recommended us as a reliable partner to a large number of important investors, contractor firms and consultants and brought numerous recognitions.

The **IMS Institute** is accredited as a research and development institute in the field of technical and technological sciences (civil engineering, mechanical engineering, energy...), where it achieves significant results in basic and applied research, transfers acquired knowledge to the economy, trains personnel and invests in research infrastructure. In addition to regular work, the research staff is engaged in research projects, cooperates with a large number of related institutions, organizes a large number of scientific and professional meetings, publishes research results in international and domestic journals and applies developed technical solutions and patents.

The **IMS Institute** is the only representative from Serbia in the European Network of Construction Research Institutes (ENBRI), as the only member of this association of top European institutions from a country outside the European Union.

With its tradition, exceptional personnel potential, equipment and technical resources at its disposal, the mission of the **IMS Institute** is to provide highly professional services in the field of its activity, i.e. to bring the construction and metal industry and energy industry of Serbia and the region closer to modern European ones through research and development, control and experimental activities. requirements and standards.

The vision of the **IMS Institute** is to maintain its position among the leading multidisciplinary scientific and research organizations in Serbia and the region, with participation in all significant projects in the field of construction and metal industry and energy through the placement of high-quality commercial services and thus contribute to the development of Serbia and the region through application of the results of scientific work in the economy.

The aim of the IMS Institute, in cooperation with its business partners, is to maintain a leading role in the field of testing and research of materials, products and technologies and to contribute to the development of Serbia and the region through the application of the results of scientific work in the economy.



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About the institute

In 1956, First units for organized product development through welding, research and control were launched in the then **Gosa** enterprise in Smederevska Palanka and they are considered to be the forerunner of today's **Gosa Institute** LLC. During the same year, by decision of the government of Socialist Republic of Serbia, Bureau for Education of Executives in Commerce was established with the head seat in Belgrade, only to change its name ten years later into Institute of work organization and business automation – Organomatik. Studies and elaborate carried out at the Organomatik Institute were fully implemented. The aforementioned Bureau is a legal predecessor of the **Institute Gosa** LLC. **Institute Goša** LLC of today, pursuant to laws was registered (transferred) to the Business Registers Agency with a decision dated July 14, 2005.

Goša Institute's mission is research and development of technologies and services for use in economy which are in accordance with European standards, along with constant education of personnel for the needs of science and industry in the fields of technical, technological and natural sciences, improving scientific bases and enhancing the well-being of the community. The determination of the Goša Institute is to provide its users with services of stable and recognizable quality, with competent and professional appearance on the market, while simultaneously monitoring and recognizing the demands of the economy and the challenges of science, and responding to changes.

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- to develop innovative technologies through high quality research and to implement them within the industry,
- to develop new research, education and innovation models in the domain of academic and industrial research,
- to promote high technologies on the national and international level and
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About the company

MIP PROCESNA OPREMA LLC is a metal processing industrial company established as a limited liability company with private capital.

MIP emerged from the company “Zokil” founded in 1954 in Čuprija, within the railway as the “Car and Locomotive Repair Facility”. Later transformations and reorganizations led to a change of name to **MIP Čuprija**. A social enterprise with a large number of employees, which covered a large number of industry branches in the field of metal processing. The company was organized into Basic Organizations of Associated Labor (OOUR), with one of the OOURs named “HIDROFOR” with its basic production activity of making hydrophore vessels, tanks, and process equipment. The company PC “**MIP Procesna oprema**” was created from the aforementioned OOUR, which was later transformed into a limited liability company under the current name.

Today, **MIP Procesna oprema** employs around 100 employees.



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About the company

TIM-INVEST d.o.o. is a company engaged in engineering, production, and services, founded in the year 2000. The company is headquartered in Belgrade. Our business orientation and main activities include foreign and domestic trade, engineering, and consulting in the fields of energy, mining, and metallurgy within the territory of Serbia and the former Yugoslav republics.

Given that our largest clients are public enterprises in the mining and energy sectors, we have also specialized in operations related to public procurement.

Through many years of representation and successful cooperation with renowned European steelworks, forges, and foundries, Tim-Invest d.o.o. has established itself as a leading distributor of pre-machined and fully machined steel forgings and castings of various weight classes — from 100 kg up to 37,000 kg — with a focus on the production of high-quality, dimensionally specific machine parts made from a wide range of materials and in accordance with demanding technical specifications, based on client documentation or the manufacturer's production program.

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About the company

TSG Industry Service provides a total solution to all your inspection and quality control needs of pressure equipment. We deliver, whether you need prompt turn-around with an inspection, or a quick answer to a technical question.

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The range of services is:

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- Putting in to service of the new pressure equipment and installations
- Testing of the system integrity
- Determination of the periodic inspection schedule and plan maintains
- Performing qualified on site periodic inspections

Periodic inspections in Republic of Macedonia are carried according to the national legislation, the Rulebook for using pressure equipment, "Official Gazette of R.M. No. 32/2009".

Types of inspections defined with the Rulebook are:

- Putting into service
- Periodic outside inspection
- Periodic inside inspection
- Periodic inspection of integrity



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About the company

Goša Montaža is a leading company in the segment of production and erection of equipment, pipelines and all types of steel structures, in Serbia and the Western Balkans region.

With 100 years of experience in the erection of all types of steel structures, pipelines and equipment as well as 30 years of experience in the field of fabrication, we have gained a reputation primarily in the energy sector through construction and maintenance of equipment for hydro and thermal power plants, (surface and underground mines) mining equipment, oil and metallurgical industry.

We confirm our strategic commitment to maintain our competitive position in the market by investing in our own capacities and realize our program as a leader in the mechanical engineering sector.

The complete scope of Goša Montaža AD activities consist of:

- design and shop drawing elaboration
- fabrication of equipment, pipelines and all types of steel construction
- erection of equipment, pipelines and all types of steel construction
- overhauls, modernization, reconstruction and revitalization of the plant as part of planned and ongoing maintenance
- providing transport and mechanization services related to projects
- providing external services for renting means of transport and mechanization

We have production facilities fully equipped to function as independent production units, each with a technologically complete production process that covers an area of 14.000 m².

Welded constructions are part of our production program. Welding operations are performed by professionally trained welders certified according to ISO 9606-2; 9606-4; under the supervision of educated personnel according to world standards and rules of the International Institute of Welding (IIW).

In accordance with the requirements of the profession and the market, the complete process from design to installation is harmonized with the generally accepted standards EN 1090-2, and welding works with the standards EN ISO 3834-2 and DIN 18800-7. We operate through an integrated management system. We are specialized in the production of pressure equipment in accordance with the European PE directive.

As part of the QA/QC Department, we are trained and certified according to EN ISO 9712 for testing welded joints by non-destructive methods. We possess international certificates for testing steel structures as well as for testing welded joints of pressure equipment (testing by visual method, magnetic particles, penetrants and ultrasound).

The base of our success are trained and professionally skilled staff, providing high quality products and services within the agreed deadlines, implementing the norms of health and safety at work and environmental protection.

Staying true to vision and values of Goša Montaža in partnership with the DSD Group further strengthens own position as a leader in the industry paving the way to the greater efficiencies and significant increase of the presence in the markets in Serbia and EU for both Goša Montaža and DSD Group for the years to come.

This partnership underscores our commitment to evolve and expand our expertise in the field of mechanical engineering impacting customers, the industry and the community as a whole.



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About the company

Smart Steel was founded in year 2019. as a result of longterm experience in the fields of industrial energetics, automatisaton and process equipment.

Smart Steel is the trademark name for successful and innovative business in the field of housing and commercial buildings automatisaton, as well as the automatisaton of industrial premises.

Our vision is to be strong global company for our clients, partners and employees recognisable by its values:

- Excellence is what makes us the best
- We change the world with our innovativity
- Integrity is the essence of our business
- We always strive to greatest accomplishments
- Human care is the foundation of our success
- Our business philosophy is based on integrity, honesty and respect we have earned with our expertise and dedication to achieve best solutions for our clients.

Smart Division is focused on the needs of its users who live in a dynamic and fast changing environment which leaves very little time for everyday obligations.



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About the company

The limited liability company **EMO TECHNIQUE DOO** is registered at Generala Štefanika 41, 11010, Belgrade (Voždovac), Serbia and has been operating since 25.08.2020.

The owner of the company is Mirjana Opačić, while the main activity of the company is registered under the code 4669 - Wholesale of other machines and equipment. The company is classified as a micro-enterprise according to the criteria defined by the Law on Accounting of the Republic of Serbia. The company offers services and equipment related to non-destructive testing, using state-of-the-art methods, including but not limited to:

- Digital radiography
- Acoustic pulse reflectometry
- Advanced ultrasonic testing (PAUT and ToFD)
- Classic test methods

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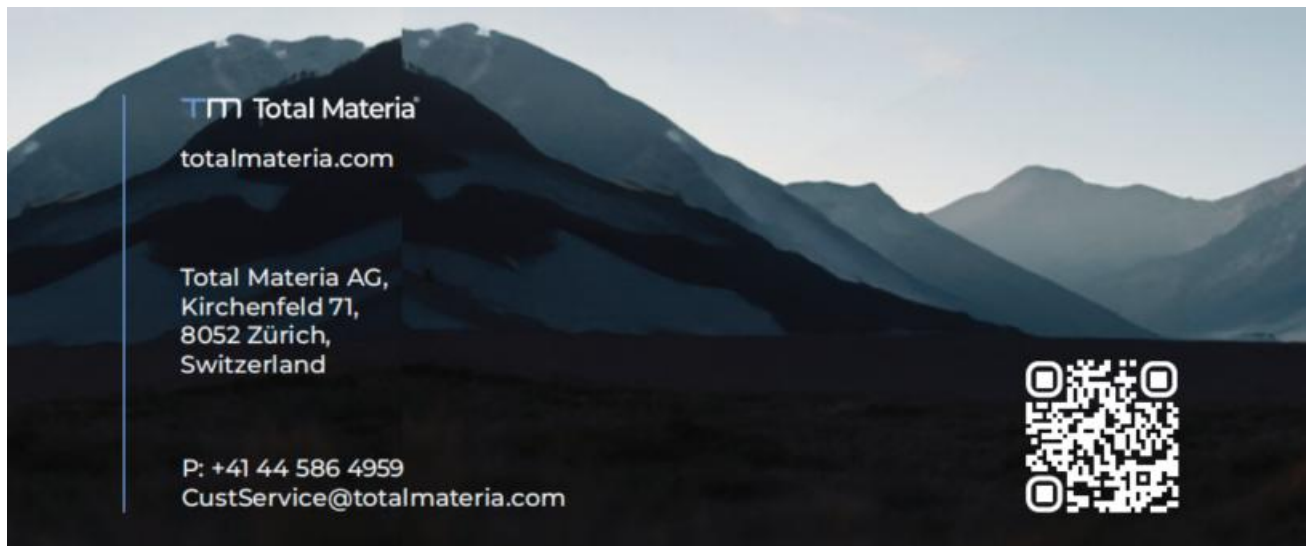
About the company

As pioneers and global leaders in our niche, our journey began with the launch of our first online materials database in 1999, setting a new standard for innovation and excellence. Since then, we have maintained our leading market position by continuously pushing the boundaries of possibility through relentless innovation and product development.

Over the past 25 years, we have expanded our niche by addressing an ever-widening array of engineering challenges related to materials. Our commitment to staying ahead of the curve has enabled us to not only meet but exceed the evolving needs of our customers, solidifying our reputation as the go-to resource for cutting & bleeding-edge solutions in our field.

Our main principles are building trust and reducing uncertainty, our dedication to customers with unparalleled support and worldwide presence and leadership through innovation with relentless investment into the development of products and services.

Total materia's mission is to To deliver the best-in-class materials information solutions to companies, partners, and the global engineering ecosystem. Our vision is to help the world to select the best-performing materials for innovaiton, savings and sustainability.



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