ICDM 2025

Conference Abstract Book

(Organized by Mini-Symposia)

ICDM 2025

MS0- General Submission

Abstract Title	Pixel level segmentation and surface wear evaluation of railway rail surface running band
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Mingjing Yue[1,2], Jian Yang [1,2], Xiancai Yang[1,2], Zeyu Liu[1,2], Jingmang Xu[1,2*], Ping Wang[1,2], Yao Qian[1,2], Allen A. Zhang[1,2] [1]Key Laboratory of High-speed Railway Engineering [2] Southwest Jiaotong University Email: yuemj2042@my.swjtu.edu.cn
Abstract	
The rail is a vital component of track structure, directly subjected to train loads, providing a continuous rolling contact surface. Due to cyclic wheel-rail contact, the rail surface forms a strip-shaped feature called the running band, which visually reflects the interaction between the wheels and the rail. The running band serves as a key indicator for track condition, helping to detect rail issues such as flatness, damage, and wear. This study proposes a method for evaluating rail optical band wear by combining 2D image semantic segmentation and 3D point cloud data analysis. The method utilizes 2D images from a 3D laser scanner and 3D point cloud data to achieve accurate identification and wear analysis of the running band. First, pixel-level semantic segmentation of the running band is performed using 2D images, with the boundary extracted by a convolutional neural network (CNN). Then, the degree of wear is calculated along the centerline and side boundaries of the running band using 3D point cloud data. Experimental results show that the method effectively integrates image information and 3D features to accurately detect and assess wear in the rail running band, demonstrating high precision, robustness, and significant potential for real-world railway applications.	

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	A combined damage model for fracture in composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Harshdeep Sharma[1], Akhilendra Singh[1] [1]Indian Institute of Technology Patna Email: harshdeep_2121me06@iitp.ac.in

Abstract

This work presents a fracture simulation framework for composites by integrating a physically consistent mixed-mode cohesive zone model with a localizing gradient damage model. The framework is implemented in Abaqus 6.14 through a user element (UEL) subroutine, this approach ensures physical consistency in mixed mode fracture using a standard damage activation function. Zero-thickness cohesive elements are generated efficiently using the cKDTree data structure from Python's SciPy library, enabling fast neighbor node searches with O(log n) time complexity. The robustness of this framework is validated through numerical examples, including a benchmark single-fiber composite test. Energy dissipation and work potential plots are generated for each numerical experiment.

Key words: Cohesive zone model, Localizing gradient damage model, UEL, Composite, Mixed-mode fracture

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	A physically small crack growth model based on CTOD
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Lindong Chai[1], Dian Wang[1], Yihai He[1], Wei Zhang[1,*] [1]Beihang University Email: zhangwei.dse@buaa.edu.cn

Abstract

In this study, a prediction model driven by crack tip opening displacement (CTOD) is proposed to account for the physically small crack growth. Firstly, an in-situ SEM testing indicate that CTOD can be a unique crack growth driven parameter. Then, considering the difference of crack closure and crack tip plasticity between small cracks and long cracks, the CTOD model for physically small cracks is developed by modifying Dugdale's model. Subsequently, a crack growth model is established for both of the small cracks and long cracks. In addition, a criterion of the transition crack length from physically small cracks to long cracks is given. Finally, several datasets of different alloys are used to validate the proposed model. For the materials involved in the current study, the model predictions agree well with the experimental data. And the calculated transition crack length is approximately consistent with that estimated from the experimental data trend.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	A new threshold model for physically small crack and long crack based on CTOD
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Dian Wang[1], Lindong Chai[1], Yihai He[1], Wei Zhang[1,*] [1]Beihang University Email: zhangwei.dse@buaa.edu.cn

Abstract

The assessment of fatigue strength of structures containing cracks is crucial for engineering design. Many studies have suggested that the threshold of the crack arrest is correlated with the crack length rather than remains a constant ($\Delta\sigma_{fl}$ or ΔK_{th}). In this study, a physically small crack threshold model based on crack tip opening displacement (CTOD) is proposed. Firstly, an in-situ SEM crack growth testing and a unified physically small crack (PSC) and long crack (LC) growth model are briefly reviewed to demonstrate that CTOD serves as a unified driving parameter for PSC and LC. Subsequently, considering the crack closure and microstructural dissimilitude, the threshold CTOD model is established. Thus, the threshold stress and corresponding non-propagating crack length can be calculated. Finally, several datasets for various materials and loading conditions are used to verify the proposed model. The model prediction has a good agreement with the experimental data. Additionally, a comparison between the proposed model and main small crack threshold models is conducted. The relationship between the transition crack length from PSC to LC and the El Haddad parameter is also discussed.

ICDM 2025

MS1-Sustainable mechanical performance of cementitious materials

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Microstructural Damage Evolution of Freeze-Thawed Shotcrete by an Integrative Nano-CT and Nanoindentation Approach
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Mengxin Liu[1, 2], Pizhong Qiao[2], <u>Lizhi Sun</u>[1] [1]University of California, Irvine [2] Shanghai Jiao Tong University Email: lsun@uci.edu

Abstract

It is crucial to investigate the evolution of microstructure to understand the deterioration mechanisms of shotcrete under cyclic freezing and thawing (F-T). In this study, nanoindentation and X-ray nano-CT techniques are integrated to characterize microstructural damage of shotcrete and its evolution due to F-T actions. An integrated statistical method of nanoindentation and nano-CT (NI-NCT) is developed with the Gaussian mixture deconvolution method to demonstrate the increase and correlation of the heterogeneous phase in cement paste and interfacial transition zones in the process of F-T cycles. The micromechanical property allows to segment the CT images of cement paste into pores/cracks, porous phase, calcium silicate hydrate, and calcium hydroxide/unhydrated clinker. The integrated NI-NCT method can provide new knowledge on the evolution law of F-T-induced damage in cement paste and serve as an effective tool in characterizing and quantifying the damage and its evolution process for cement-based heterogeneous materials.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Deciphering the strength origins of LC^3: Insights into mechanical performance, predictive modeling, and carbon emission characteristics
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Qi Luo[1*], Xinyu Zhang[2], Jiaqi Zhang[2], Lu Fan[2] [1] Department of Civil and Architectural Engineering, Aarhus University, Aarhus 8000, Denmark. [2] School of Civil Engineering, Chongqing Jiaotong University, Chongqing 400074, China. Email: qiluo@cqjtu.edu.cn

Abstract

Limestone Calcined Clay Cement (LC^3) has emerged as a promising low-carbon alternative to ordinary Portland cement (OPC), significantly contributing to global carbon neutrality goals. By replacing over 50% of cement with calcined clay and limestone, LC^3 achieves comparable mechanical performance while substantially reducing CO_2 emissions. Despite its successful adoption in various applications, the strength origins of LC^3 remain partially unresolved. Key questions include whether impurities in calcined clays hinder performance and whether higher-grade clays yield stronger and more sustainable LC^3 formulations. Addressing these uncertainties is crucial for the future scalability and optimization of LC^3.

This study systematically explores the mechanical performance of LC^3, with a detailed investigation into the influence of impurities on strength development. By employing machine learning techniques, a predictive model for LC^3 strength is developed to better understand and optimize its mechanical behavior. Furthermore, using a life cycle assessment (LCA) framework, the study evaluates the carbon emissions associated with different clay grades and processing strategies. The findings provide valuable insights into the strength origins of LC^3, offering guidance for its broader adoption and sustainable application in construction industries worldwide.

Abstract Title	The Impact of Portlandite, Calcite, Quartz, and Ettringite Inclusions on the Multiscale Mechanical Behavior of the C-S-H Matrix
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zhe ZHANG[1], Guoqing GENG[1] [1]National University of Singapore Email: zachz_24@nus.edu.sg

Abstract

C-S-H serves as the primary binder in cement, alongside additional phases that influence its performance. Understanding the impact of these phases on cement strength is crucial. This study introduces an innovative approach to creating a binary system containing C-S-H and various additional phases to investigate their effects on composite strength. By blending C-S-H with selected minerals, we precisely control the mineral content. Multiscale techniques, including atomic force microscopy (AFM), hardness, and modulus measurements, are employed to quantify the influence of these minerals on C-S-H composites.
The results demonstrate that the intrinsic moduli of the added phases significantly affect the composite's hardness, while cohesion influences the compression modulus. For instance, quartz exhibits a higher intrinsic modulus but lower cohesion compared to C-S-H, leading to greater hardness but a reduced compression modulus. Ettringite reduces both hardness and compression modulus, while the effects of calcite and portlandite remain unclear due to their lower cohesion but higher intrinsic modulus. These findings provide valuable insights for improving the performance of cementitious composites.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	A coupled thermo-elastoplastic-damage model for nano-silica incorporated concrete
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xiaoyan Man[1], Aiqing Xu[1], J. Woody Ju[1] [1]University of California, Los Angeles Email: juj@ucla.edu

Abstract

The incorporation of nano-silica enhances the performance of concrete; however, the damage response and mechanical properties of nano-silica incorporated concrete under or after high temperatures remain insufficiently investigated. To fill this gap, a coupled thermo-elastoplastic-damage model is developed in this study. In the model, we consider the coupled effects of temperature-induced degradation of mechanical properties and elastoplastic damage evolution caused by external loads, establishing a novel constitutive model to describe and predict the mechanical behavior of concrete under or after high-temperature conditions. Through a multiscale chemo-micromechanical model, spanning from the C-S-H matrix to concrete, the thermal damage evolution of nano-silica incorporated concrete is characterized, and a thermal damage parameter is introduced to quantify the extent of thermal damage. Within the framework of damage mechanics, the total strain tensor incorporates the mechanically related elastic and plastic strains, as well as the temperature-dependent free thermal strain and transient creep strain. Two isotropic damage parameters are employed to describe the damage evolution of concrete under external loading, which is extended to a 4th-rank damage tensor. The proposed model is numerically implemented using finite element software and validated through comparisons with experimental results, demonstrating its robustness and reliability in simulating the stress-strain response and damage evolution of nano-silica incorporated concrete under different temperature and stress conditions. Finally, based on this model, the influence of different parameters on the damage response and mechanical performance of nano-silica incorporated concrete is systematically investigated, providing valuable insights and an effective theoretical basis for predicting and optimizing the complex mechanical behavior of nano-silica incorporated cementitious composites.

Abstract Title	Age-related degradation of graphene oxide and its influence on the properties and morphology of cement mortar with graphene oxide
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	S. Ganesh, C. Thambiliyagodage, S. V. T. J. Perera and <u>R. K. N. D. Rajapakse</u> Sri Lanka Institute of Information Technology (SLIIT), Colombo 10115, Sri Lanka. Email: nimal.ra@sliit.lk

Abstract

Graphene Oxide (GO) is known to enhances the structural properties of cement composites. However, GO reduces its chemical characteristics with ageing. Hence, the age of GO may affect the properties of GO-incorporated cement composites. This study determines the effects of age of GO when incorporated into cementitious composites. The study investigated the effect of age of GO of up to 35 weeks, where the GOs' were characterized at different ages using Fourier-transform infrared spectroscopy, Raman spectroscopy, X-ray Photoelectron Spectroscopy, X-ray powder diffraction (XRD) and Scanning electron microscope (SEM). The effect of ageing of GO on the properties of cement mortar and paste was studied by considering well established physical properties. Based on experimental studies, it is found that GO must be used within 13 weeks from production to achieve favourable results. The morphology of the cement mortar was studied via XRD, Brunauer-Emmett-Teller analysis, SEM, and Energy-dispersive X-ray spectroscopy.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Modified concrete damage-plasticity model for ultra-high-performance concrete
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hongyi Yang[1*], Leong Heng Poh[1] [1]Department of Civil and Environmental Engineering, National University of Singapore Email: hyang@nus.edu.sg

Abstract

The Concrete Damage-Plasticity Model II (CDPM2)[1] is one of the built-in models for cementitious materials in LS-DYNA. While there are many material parameters in CDPM2, in the absence of relevant experimental data, most of these parameters can adopt recommended values, or be estimated based on the concrete strength. The predictive capability of CDPM2 has been demonstrated for normal strength concrete (NSC) in the literature [2,3], for complex loading paths and/or sophisticated multiaxial stress states. However, the direct application of CDPM2 with the recommended and auto-generated parameters to ultra-high-performance concrete (UHPC) is problematic, as the latter exhibits distinct material properties and mechanical behavior that diverge significantly from NSC. The objective of this presentation is to focus on the necessary modifications to CDPM2 specifically for UHPCs, focusing on the yield surface, hardening and softening evolution laws. The modified CDPM2 is next validated by comparing simulation results against experimental data for concrete infill steel structures, to demonstrate the potential applications of the modified CDPM2.

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MS2-

Machine learning in damage mechanics

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Transfer and ensemble learning enable prediction of flexural strength in fully-graded concrete with insufficient experiment and simulation
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xin Wang[1], Xiangnan Qin[1*] [1]School of Water Conservancy and Transportation, Zhengzhou University, Zhengzhou 450001, China Email: wangx9260@163.com

Abstract

The majority of current research on the fracture behavior of fully-graded concrete are conducted with mesoscale modeling and physical experiments. However, both experimental and computational methods are resource-consuming and equipment-demanding in determining the fracture parameters of large-scale specimens with oversized aggregates. Machine learning (ML) techniques provide an alternative, but data scarcity increases overfitting risk and prediction errors. This study developed a transfer learning model based on ML to predict the flexural strength of large-scale three-point bending (TPB) specimens. Firstly, a source domain dataset was established by combining physical experiments and numerical simulations for small-scale aggregates and components. Subsequently, the results show that the integrated learning algorithm such as RF can predict the model better, compared with Decision Trees (DT) and Random Forest (RF) algorithms. This study further incorporates four additional Boosting-based ensemble learning (EL) algorithms, including XGBoost, LightGBM, CatBoost, and AdaBoost, and the CatBoost algorithm demonstrates a fracture parameter prediction with smaller error parameters and reaches an R2 value of 0.98 on the test set. On this basis, a novel transfer learning model named TrCatBoost is proposed. The proposed model demonstrates exceptional robustness and generalization ability in the process of transferring knowledge from smaller-scale models to larger-scale ones.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Machine learning assisted calibration of an extended GTN model
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Chenyang Zhang[1], Xincun Zhuang[1], Zhen Zhao[1,2] [1] Institute of Forming Technology and Equipment, School of Materials Science and Engineering, Shanghai Jiao Tong University, Shanghai 200030, China [2] National Engineering Research Center of Die & Mold CAD, Shanghai Jiao Tong University, Shanghai 200030, China Email: zhang-chenyang@sjtu.edu.cn

Abstract

To accurately describe the microscopic damage behaviors and predict the ductile fracture under different conditions, the damage models are usually coupled with different constitutive models and modified with damage evolution equations. However, these models always have many introduced parameters, which brings great trouble to the efficiency and accuracy of parameter calibration, and finally limits the general use of models. In this study, a machine learning assisted method was proposed to calibrate the parameters of the modified Gurson-Tvergaard-Needleman (GTN) damage model, which considers the anisotropy of materials and a broad range of stress states. Three different artificial neural network (ANN) structures with distinguished inputs were constructed, which contains local displacement fields and global force-displacement curves respectively. The training database was generated in the parameter value space via FE simulations, which includes the tension tests of smooth round bar and the shear tests of butterfly specimen. The corresponding experimental data obtained by Digital Image Correlation (DIC) was fed to the trained ANN models to calibrate the parameters. Both efficiency and accuracy of the proposed calibration method was evaluated by comparing with the inverse method.

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Including Bayesian Uncertainty into the Finite Element Simulation of Progressive Damage in Composites: Opportunities and Challenges
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Johannes Reiner[1] [1]Deakin University, Australia Email: johannes.reiner@deakin.edu.au

Abstract

Fibre Reinforced Polymer (FRP) composites can suffer from a wide range of variability in their mechanical behaviour. This uncertainty mainly stems from manufacturing-induced defects and imperfections, including fibre misalignment, inconsistent fibre volume fraction, and wrinkling. Regarding the simulation of mechanical behaviour, the question arises as to how to include these uncertainties and variabilities.

This presentation introduces a robust framework [1] for considering uncertainties in the Finite Element (FE) simulation of non-crimp carbon fibre fabric composites subjected to progressive fracture tests [2]. This framework incorporates a combination of various analyses techniques, including global sensitivity analyses, surrogate modelling, and Markov Chain Monte Carlo for the Bayesian estimation of FE input parameters [1, 2]. It is demonstrated that FE simulations using the obtained distributions of input parameters can effectively represent the uncertainty measured in experiments.

The capability of the framework to represent uncertainty is validated against a series of open-hole tension tests to determine design allowables virtually. The simulation results are compared with various calculation methods using experimental measurements [2].
Furthermore, the lessons learned regarding the incorporation of uncertainty via Bayesian methods are discussed, outlining common opportunities and challenges concerning experimental testing, the underlying FE modelling, the selection of surrogate model, as well as decisions within the Bayesian estimation process.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Damage mode identification and decoupling in CFRPs by an interpretable and lightweight convolutional neural network
List of authors & their affiliations with the presenter's name underlined . Provide email contact for the presenter.	Menghan Zhang[1], Yumei Zhao[1], Jie Zhi[1], Bin Yang[1] [1]Tongji University Email: 2410235@tongji.educn

Abstract

Carbon fiber reinforced polymer composites (CFRPs) have found extensive applications in various industrial areas. However, they are susceptible to various internal damage mechanisms under loading, which may not be immediately visible on the surface, thereby creating significant challenges for accurate structural performance evaluation. This study proposes an interpretable convolutional neural network (CNN) for damagemode identification and decoupling within CFPR composites, which integrates high predictive accuracy, broad applicability, and practical deployability. CT scan images of impact-loaded specimens are collected and preprocessed, with the observed damage modes classified into three categories based on their micro-morphological features: matrix cracking, delamination, and fiber fracture. The developed CNN model achieves 100% and 92.99% classification accuracy for single and combined damage pattern, respectively, indicating its capability for precise damage identification and effective decoupling of multiple damage characteristics in com plex damage scenarios. Furthermore, the proposed model demonstrates strong generalization capa bility in detecting damaged areas, which has been successfully validated through real-time damage monitoring application using glass fiber composite laminates. The three patterns of damage examined are, on one hand, mechanically associated with the impact energy and laminate structure, and on the other hand, representing a progressive damage sequence from matrix cracking (mild damage) to fiber fracture (severe damage). The study further concentrates on time-dependent damage evaluation, aiming to develop a robust capability for accurate and efficient detection and classif ication of internal damage, particularly for industrial applications demanding frequent structural inspections. The findings suggest that the proposed CNN-based framework represents a promising and reliable solution for automotive engineering applications, especially in structural health monitoring and damage assessment of composite structures.

Abstract Title	A CNN-BASED DEEP LEARNING FRAMEWORK FOR PREDICTING FRACTURE PROPERTIES OF QUASI-BRITTLE MATERIALS
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xiaowen Chen[1,2] and Leong Hien Poh*[1] [1]National University of Singapore [2] Shanghai Jiao Tong University Email: e1327992@u.nus.edu

Abstract

Many computational models have been proposed in the literature to describe the complex mechanical response of composites at the meso-scale, from which fracture properties at the macro engineering scale can be determined. However, the simulation cost associated with a typical 3D problem may be intractable. To this end, machine learning-based approaches to predict macroscopic properties from the underlying meso-scale unit cells are gaining more attention. In this presentation, we investigate the prediction of mechanical properties of 3D representative volume elements (RVEs) of two-phase materials containing matrix material and pores. From the given 3D RVEs, we consider various input scenarios in a CNN framework, to obtain the macroscopic properties including the elastic modulus, tensile strength, and fracture energy. The focus lies in defining an efficient CNN architecture to obtain accurate predictions efficiently, i.e. at a low offline training set-up cost.

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	Open-hole tension strength prediction with machine learning
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jacintha Y.Y. Loh[1], Vincent B.C. Tan[1] and Tong-Earn Tay[1] [1]Department of Mechanical Engineering, National University of Singapore, Singapore Email: e0424995@u.nus.edu

Abstract

Fiber-reinforced composites (FRCs) are widely used in engineering applications due to their exceptional specific strength and stiffness. The open-hole tension (OHT) test is a common mechanical strength test for composites [1]. Although advanced finite element modelling (FEM) has been used for prediction of OHT strength [2], it remains computationally intensive for moderately thick composite laminates. In recent years, there has been a growing interest in using machine learning (ML) to study progressive damage in FRCs [3]. These ML models, trained on data from simulations and experiments, could expedite failure prediction in FRCs and make progressive damage analysis more efficient. In literature, some ML training data is generated from simplified progressive damage models by excluding certain failure mechanisms such as delamination in order to increase efficacy of data generation [3]. However, this may result in inaccurate predictions, especially in cases where delamination is not insignificant.

The objective of this research is to use ML to predict OHT strength and failure strain from laminate properties, for ply blocked FRCs with IM7-8552 carbon/epoxy composites and stacking sequence $[w_4/x_4/y_4/z_4]_s$, where w, x, y and z are fiber angles.

Depending on the ply blocks and relative thickness of the plies, the failure mechanism of OHT specimens may be brittle, delamination dominated, or partial [4]. A recently developed explicit FE model [2] – which employs a discrete crack model (DCM) technique known as floating node method (FNM) – was found to be capable of modelling progressive damage due to fiber failure, matrix cracking and/or delamination. This explicit FE model has been validated with limited experimental data and is more efficient (shorter CPU times) than implicit FE model.

To generate training data, we iteratively run the explicit FE model using different combinations of w, x, y and z values. w, x, y and z can assume any of these values: 0, ±20, ±30, ±40, ±60, ±75, 90 degrees, but must be distinct from one another. For example, $[-20_4/60_4/0_4/-40_4]_s$ is a valid training datapoint but $[-20_4/60_4/0_4/60_4]_s$ is not. OHT strength and failure strain extracted from each FE model

were used to train an ML model. Subsequently, ML model performance was evaluated by using the trained ML model to predict OHT strength and failure strain for 24 quasi-isotropic (QI) and 24 non-QI unseen test cases. Non-QI validation set differs from training data in terms of order of inputs, while QI validation set differs from training data in terms of input values. For each prediction, differences between ML-predicted and FE-predicted values in strength and failure strain are presented as percentage errors with respect to the FE results. An accurate prediction is defined as one with both OHT strength error and failure strain error within ±10%.

Two sets of data with different OHT strength definitions were considered – one for ≥2% load drop from peak and the other for ≥10% load drop from peak. The dataset with ≥2% load drop captures early damage of OHT specimens while that with ≥10% load drop captures more significant damage of OHT specimens. For each dataset, three ML techniques were used: train test split, active learning and hyperparameter tuning. Train test split was used to quickly estimate the performance of an ML model in predicting unseen data, thereby facilitating the shortlisting of suitable ML models. Based on the ML models chosen, active learning (which iteratively selects the most informative data as training data) and hyperparameter tuning (which changes a ML model's structure, complexity and learning rate) were used to maximise the number of accurate predictions while reducing training data required. Since data generation is still in progress, active learning and hyperparameter tuning were carried out independently to determine their individual effect on prediction accuracy.

Considering the three ML techniques and up to 10777 training data, number of accurately predicted validation cases for the two datasets are as follows:

1) ≥2% load drop: 23 out of 24 non-QI and 10 out of 24 QI
2) ≥10% load drop: 23 out of 24 non-QI and 17 out of 24 QI

Details including the exact number of training data used and how prediction accuracy (such as root mean squared error, mean absolute error, and number of accurate predictions) changes with increasing training data will be presented at the conference.

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Date-driven model of rock fractures subject to direct shear
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zhihong Zhao[1], Jinfan Chen[1] [1]Tsinghua University Email: zhzhao@tsinghua.edu.cn

Abstract

A huge number of empirical, semi-theoretical, and theoretical models have been proposed and developed to predict shear behavior of rock fractures. Fracture surface roughness is an important parameter in those models, and accurately describing fracture surface roughness usually determines the model accuracy. However, characterization of fracture surface roughness has been a challenging task, and the existing surface roughness parameters may not fully represent the 3D characteristics of fracture surfaces. With rapid development of laser scanning technology, surface morphology data can be easily measured using 3D laser scanner. Therefore, using the obtained point-clouds of fracture surfaces as input, date-driven model is trained to predict shear behavior of rock fractures based on cross-domain knowledge transfer algorithm. In this way, the difficulty in characterizing fracture surface roughness is avoid. The developed data-driven model is validated by different types of fractured rock samples.

MS3-

Multiscale and Multiphysics Modelling of Damages in Viscoelastic Materials

The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Multiscale Modeling of Fracture and Deformation in Heterogeneous Viscoelastic Media: Modeling Concept and Example Cases
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Santosh Reddy Kommidi[1] Yong-Rak Kim[1] [1]Texas A&M University Email: yong-rak.kim@tamu.edu

Abstract

Modeling of fracture and deformation of heterogeneous viscoelastic solids is a complex subject because the mechanical behavior of such media is strongly dependent on various factors, including microstructural characteristics, the time- and rate-dependent properties of the viscoelastic constituents, and interactions between them. Therefore, these factors must be effectively considered for accurate analysis and design, for which multiscaling has been considered a proper way to address such challenges. This study presents a two-way coupled finite element modeling that includes material viscoelasticity and an extrinsic nonlinear viscoelastic cohesive zone (NVCZ) to effectively model the fracture process of viscoelastic media. The NVCZ incorporates the internal state variable based on the Gaussian distribution function to account for the rate-dependent cracking on viscoelastic media. The finite element modeling is configured by coupling three primary length scales (i.e., microscale cracking with the NVCZ model, mesoscale representative volume element model, and macroscale homogeneous model of the entire body). The three length scales are two-way coupled (macro-meso-micro and micro-meso-macro) in each simulation time step. It can thus address the effects of spatial-temporal microstructure evolution and component-level damage due to cracking on effective material properties and constitutive behavior of the macroscale body with significant computational efficiency. The entire algorithm was implemented as a two-way coupled multiscale code. The modeling concept is introduced, and some example cases with experimental results are presented to demonstrate the capability and validity of the two-way coupled multiscaling. The results demonstrate that the method can model multiscale fracture and deformation in various heterogeneous viscoelastic media without losing key microstructural details but providing great experimental efficiency.

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Abstract Title	A multiscale damage model of concrete
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yanpeng Wang Beijing Jiaotong University Email: 10197@bjtu.edu.cn

Abstract

The presentation involves a damage model built for concrete on the basis of multiscale analysis. Specifically, the damage of a mesoscale representative volume element of concrete is defined as the average of the damages of the microscale volume elements located inside it and the evolution law of the latter is established by studying the growth rate of the microcrack inside each of them through nano-mechanics. In addition, a new kind of expression form for the damage driving force of concrete is derived. It is found that the developed model can well simulate the strengths under (quasistatic or dynamic) monotonic loading and the lifetimes under cyclic loading of concrete in various stress states.

Abstract Title	DEM modeling of shear failure behavior of shale with different bedding orientations subjected to direct shear loading
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zhina Liu, Haifeng Feng Department of Geology, China University of Petroleum-Beijing, China Email: zhinaliu2014@126.com

Abstract

It is known that the failure mechanism of anisotropic shale is extremely complex. In this study, 3D particle-based discrete element method was used to characterize the shear failure behavior of shale containing different bedding orientations through numerical direct shearing tests. This study performed numerical tests in shale samples with four bedding strikes (α= 0°, 30°, 60° and 90°) and ten bedding dips (β =0°~ 90°) to investigate the progressive damage mechanisms under direct shear tests. Model results show that the bedding orientations of shale can significantly affect both the shear failure modes and shear strength of shale. The shear strength is the largest while the dip of shale is around 50°. The evolution process of shear and tensile microcracks shows different patterns in different models. Finally, the numerical model results are compared with both experiments and natural shear fractures in shale, and showed good consistency.

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Abstract Title	Inertia effect of deformation in amorphous solids: A dynamic mesoscale model
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	M.Q. Jiang[1,2,*] 1 State Key Laboratory of Nonlinear Mechanics, Institute of Mechanics, Chinese Academy of Sciences, Beijing 100190, China 2 School of Engineering Science, University of Chinese Academy of Sciences, Beijing 100049, China Email: mqjiang@imech.ac.cn

Abstract

Shear transformation (ST), as the fundamental event of plastic deformation of amorphous solids, is commonly considered as transient in time and thus assumed to be an equilibrium process without inertia. Such an approximation however poses a major challenge when the deformation becomes non-equilibrium, e.g., under the dynamic and even shock loadings. To overcome the challenge, in this talk we proposes a dynamic mesoscale model for amorphous solids that connects microscopically inertial STs with macroscopically elastoplastic deformation. By defining two dimensionless parameters: strain increment and intrinsic Deborah number, the model predicts a phase diagram for describing the inertia effect on deformation of amorphous solids. It is found that with increasing strain rate or decreasing ST activation time, the significant inertia effect facilitates the activation and interaction of STs, resulting in the earlier yield of plasticity and lower steady-state flow stress. We also observe that the externally-applied shock wave can directly drive the activation of STs far below the global yield and then propagation along the wave-front. These behaviors are very different from shear banding in the quasi-static treatment without considering the inertia effect of STs. At last, we discuss the physical mechanism for the Swegle-Grady power law of plastic wave front. The present study highlights the non-equilibrium nature of plastic events, and increases the understanding of dynamic or shock deformation of amorphous solids at mesoscale.

MS5- Damage-coupled Constitutive Models and Their Application

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Abstract Title	A generalized Gurson model for loaded “voids”
List of authors & their affiliations with the presenter’s name underlined. Provide email contact for the presenter.	**Li. Yu**[a], Feng. Liu[a], S.L. Cai[a], L. H. Dai[a, b], M.Q. Jiang[a,b,*] [a]State Key Laboratory of Nonlinear Mechanics, Institute of Mechanics, Chinese Academy of Sciences [b]School of Engineering Science, University of Chinese Academy of Sciences Email: yuli@imech.ac.cn

Abstract

Voids are common mesoscale damage structures in materials, primarily caused by the debonding and cracking of inclusions. Their nucleation process is strongly influenced by the properties of the inclusions. The traditional Gurson model analyzes this issue by treating voids and inclusions independently. However, This approach fails to capture their coupled damage behavior accurately. To overcome this limitation, we propose the concept of loaded "voids" and redefine the Gurson model. Specifically, the model redefines "voids" as regions that encompass both voids and inclusions, where the inclusions are modeled as forces acting on the inner surfaces of the "voids", thus providing a unified framework for describing their coupled state. Based on this concept, we derive the yield surface equation and the constitutive relationship for the generalized Gurson model. Beyond the void volume fraction, the model obtains two additional damage parameters to characterize the loading state within the loaded "voids". This new model addresses the limitation of the original Gurson model under low triaxiality stress states without losing the connection between void volume fraction and damage evolution. Additionally, it can predict yield, damage, and deformation localization behaviors in various composite materials. While maintaining its simplicity, the model provides a more realistic representation of void damage mechanisms, substantially broadening the applicability of the Gurson model.

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Abstract Title	Suppression of fatigue crack initiation and propagation under low strain conditions through gradient grain refinement
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Kai Wang[1], Taoshuo Bai[1], Jingmang Xu[1] [1] Southwest Jiaotong University Email: wangkaiyours@163.com

Abstract

Grain boundaries exhibit softening under low strain conditions when subjected to cyclic rolling loads, making them potential sites for fatigue crack initiation. In this study, we developed a crystal plasticity-cohesive finite element model that incorporates the degradation of strength and stiffness at the grain boundaries of pearlitic rail steel. The effects of grain size and grain gradient on fatigue crack initiation and propagation were investigated. Besides, we propose a method for refining the rail surface grain structure through ultrasonic roll contact, creating a depth-dependent gradient in the grain distribution. This approach reduces the likelihood of fatigue crack initiation while also suppressing crack propagation. The results demonstrate that gradient grain refinement significantly enhances the wear resistance of the rail material and effectively inhibits both the initiation and propagation of fatigue cracks.

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Abstract Title	A unified multi-phase-field model for Rayleigh-Damköhler fluid-driven fracturing
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Bo Li, Hao Yu and HengAn Wu Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: Leebo@mail.ustc.edu.cn

Abstract

This presentation develops a unified multi-phase-field framework to model the mechanics enhanced chemical damage and dissolution-assisted fracturing process based on unified free energy and micro-force balance (e.g., CO_2 fracturing). Two phase field variables are introduced to characterize the morphology of the evolving solid-liquid interface; a chemical damage phase field which captures the short-range chemical damages, and a fracture phase field, which captures the long-range fracture propagation. The microstress quantities conjugated to and are derived from the principle of virtual work, yielding non-local multi-phase-field formulations. The governing equations for the Rayleigh-Damköhler fluid-driven fracturing are derived from the variational formulation of the free energy, featuring a robust four-way coupling among multiphase fluid flow, chemical damage, poroelastic mechanics, and rock fracturing. The characteristic flow structures and damage patterns are revealed in a wide range of Rayleigh, Damköhler, and Péclet numbers. When the direction of fluid flow aligns with fracture propagation, scaling laws to distinguish rock failure patterns are derived using damage morphology parameters (penetration lengths in the flow and transverse directions). In scenarios where gravity induces a misalignment between the directions of leak-off fluid flow and fracture propagation, novel damage patterns (non-invasive fracturing and fracturing/fingering) are found, and the normalized fracture number and chemical damage number are introduced to construct a comprehensive phase diagram encompassing various unstable fluid leak-off structures and rock failure.

Abstract Title	Oscillatory Instability of Fluid-driven Fracture in Porous Materials
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	WenLong Xu, Hao Yu, HengAn Wu Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: xuwl20@mail.ustc.edu.cn

Abstract

An instability in fluid-driven fractures, observed in the experiment of porous materials, is triggered by Mode-II shear deformation deviating from the crack plane. While it is known that the deviated crack (e.g., branching behavior) originates from the shear-strength degradation due to fluid invasion, the onset of periodic oscillations remains unexplained by current models. We perform an asymptotic stability analysis for a wave-shaped crack with poroelastic nonlinearity, which uncovers the intrinsic scaling for the oscillatory wavelength. It is governed by the balance between the stabilizing effect of cohesive force in process zone and the destabilizing effect of shear perturbations along crack sides. By deriving both the deflection angle and the critical unstable angle of such sinusoidal perturbations, we propose theoretical boundaries among straight, oscillating, and branching patterns to construct a stability phase diagram of fluid-driven fracture.

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Abstract Title	Simulation of Full-Life Ratcheting Behavior of U71Mn Rail in Pre-Corrosive Environment Using a Damage-Coupling Cyclic Plasticity Constitutive Model
List of authors & their affiliations with the presenter ' s name underlined. Provide email contact for the presenter.	Mengzhen Xie[1], Xiang Xu[2], Guozheng Kang[1], Qianhua Kan[1] [1]Southwest Jiaotong University [2]Nanjing Tech University Email: xiemengzhen531@gmail.com

Abstract

Under the combined effects of corrosive environments and mechanical loading, the cyclic deformation behavior and fatigue life of rail materials undergo significant alterations. Accurately assessing fatigue life in corrosive environments proves crucial for ensuring railway operational safety. Leveraging existing experimental data from pre-corrosion fatigue tests on U71Mn steel rails, this study establishes an initial damage evolution equation correlated with pre-corrosion duration. This formulation derives from the conversion relationship between life reduction under varying pre-corrosion periods and initial fatigue damage. Within the continuum damage mechanics framework, the proposed model integrates with the Abdel-Karim-Ohno cyclic plasticity constitutive model through a coupling methodology. The methodology incorporates nonlinear modifications to the saturated ratcheting parameter in back stress through two key components: the initial damage factor and equivalent stress amplitudes obtained via the stress memory surface. These modifications yield an enhanced kinematic hardening rate formulation capable of simulating ratcheting behavior across different stress amplitudes and pre-corrosion durations. Computational results demonstrate that the corrosion-incorporated model effectively simulates the ratcheting strain evolution induced by asymmetric stress cycles under varying pre-corrosion conditions. Furthermore, predicted residual fatigue lives consistently fall within the two-fold error band, validating the model's predictive capability.

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Abstract Title	Mesomechanical low-cycle fatigue damage theory of extruded AZ31 magnesium alloy
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Ziyi Wang[1], Chao Yu[2], Shengchuan Wu[2], Xiqiao Feng[1], Guozheng Kang[2] [1] Department of Engineering Mechanics, Tsinghua University, Beijing 100084, China [2] Applied Mechanics and Structure Safety Key Laboratory of Sichuan Province, School of Mechanics and Aerospace Engineering, Southwest Jiaotong University, Chengdu 610031, China Email: ziyiwang1996@foxmail.com

Abstract

Fatigue failure is a significant concern for magnesium (Mg) alloy components. However, fatigue damage mechanisms of Mg alloys, particularly in the case of ratchetting–fatigue interaction at elevated temperatures, are still not well understood. In this paper, we combine experiments and theoretical analysis to investigate the temperature dependent damage mechanisms of the extruded AZ31 Mg alloy, specifically focusing on the effects of twinning and ratchetting–fatigue interaction. We reveal that the microcrack damage, which is influenced by multiple plastic deformation mechanisms, is dominant at the room temperature, while the ratchetting induced microvoid damage is more prevalent at higher temperatures. Considering the intricate interactions involving dislocation slip bands, twin boundaries, and grain boundaries, an energy based mesomechanical damage model is firstly proposed, describing the microcrack initiation at room temperature. Then, we establish a mesomechanical damage model to rationalize the microvoid damage with the effect of ratchetting–fatigue interaction at high temperature, and a unified damage model is subsequently constructed by considering the coupling effect between microvoid and microcrack damage. This novel model can reasonably simulate the intricate process of damage evolution and predict the critical condition of microvoid or microcrack formation at varying temperatures. This work has the potential to serve as a theoretical tool for the safety design of structures made from Mg alloys under complex mechanical and thermal conditions.

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Abstract Title	Experimental Calibration of a Coupled Creep-Damage-Plasticity Model and Its Application to Creep-Sensitive Structural Components
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Tengchen Rong[1], Qing Wang[2], Xiaodan Ren[1] [1]Tongji University [2] Ocean University of China Email: rongtengchen@tongji.edu.cn

Abstract

Concrete creep significantly influences structural behavior. To address this issue, a coupled creep-damage-plasticity model incorporating bi-scalar damage variables has been proposed recently, demonstrating high accuracy in predicting creep deformation at both component and structural levels.

In this study, uniaxial compression creep experiments were performed on self-compacting concrete, with loading age and stress level as experimental variables. The results reveal that the creep deformation of early-age concrete is closely related to the loading age, while moderate stress levels induce pronounced nonlinear creep behavior. Subsequently, the experimental data were utilized to calibrate the parameters of the aforementioned model. The fitted creep coefficient curve accurately captures the trend and magnitude of creep deformation, thereby validating the model's effectiveness. Following this, the calibrated model was employed to simulate creep-sensitive structural components. The results provide practical guidance for the design of creep-sensitive structures.

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Abstract Title	A coupled damage constitutive model for carbide-free bainitic rail steel considering martensite transformation
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xiang Xu[1], Qianhua Kan[2], Guozheng Kang[2] [1]Nanjing Tech University [2] Southwest Jiaotong University Email: superxxud@126.com

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

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Abstract Title	The influence of water content on the mechanical responses of polyacrylamide hydrogels under stress-controlled cyclic loadings
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xuelian Zhang[1], <u>Junjie Liu</u>[1], Jian Li[2], Zhihong Liang[1], <u>Qianhua Kan</u>[1], Guozheng Kang[1] [1]Applied Mechanics and Structure Safety Key Laboratory of Sichuan Province, School of Mechanics and Aerospace Engineering, Southwest Jiaotong University, Chengdu, Sichuan, 611756, China [2] Shock and Vibration of Engineering Materials and Structures Key Laboratory of Sichuan Province, Mianyang, Sichuan, 621999, China Email: junjie_liu@swjtu.edu.cn (J.J. Liu) ; qianhuakan@foxmail.com (Q. H. Kan)

Abstract

In this work, polyacrylamide (PAAm) hydrogels with different water contents (WCs) were prepared, and stress-controlled cyclic experiments were carried out. The effect of water content on the mechanical behavior of PAAm hydrogels was observed through stress-strain curves, apparent modulus, and dissipation energy across various loading cycles. It is concluded that with the increase in the WC, the peak and valley strains and the dissipation energy increase while the apparent modulus decreases. The WC significantly influences the evolution of dissipation energy with the increase of the loading cycles. For PAAm hydrogels with a relatively high WC (from 96% to 67%), the dissipation energy decreases appreciably between the first and the second loading cycles and then remains stable with increasing the loading cycles further. However, for PAAm hydrogels with a relatively low WC (50% and 34%), the dissipation energy decreases significantly between the first two cycles and then increases with increasing the loading cycles. Residual strain was found after cyclic loading and a physically-based visco-hyperelastic-plastic model was developed to describe the response of stress controlled cyclic loading.

MS6- Impact Damage and Fracture of Materials and Structures

Abstract Title	Field Investigation of Dynamic Response Concrete Bridge Piers under Explosion
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Abstract

To study the blast resistance of reinforced concrete (RC) bridge piers when subjected to explosive loads, this study conducted an field test on a three-span simply supported bridge featuring circular-section double-column piers. The analysis focused on the failure characteristics, damage level, and dynamic response of the double-column piers with circular-section subjected to both in-contact and non-contact explosive loads. The findings indicate that the failure mode of the bridge piers might shift from a local shearing failure mode to a bending failure mode due to variations in explosive equivalent and structural dimensions. Nevertheless, the extent of rupture in transversal and vertical directions is found to be dependent on the sectional stiffness in the corresponding directions, entailing local compressive and inclined shear cracks. In addition, the reinforcement shape after yielding at the location of rupture deviate from those observed in conventional bending failure. Compared to contact explosions, non-contact explosions result in significantly less damage at the equivalent of explosive mass due to the faster dissipation of energy. The diffraction effect of the shockwave, which is attributed to the large dimensions of the bridge columns and their large energy consumption capacities in the blast-facing surface, can be neglected in the anti-blast analysis of pier bodies. However, the confinement effect in the space beneath the bridge and the reflection of the ground and embankment must be taken into account in the analysis. For simplified design and analysis, double-column piers can be modeled longitudinally as pin supports at the top with two fixed ends when conducting transversal analysis.

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Abstract Title	Scaling laws for two-sphere collision
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	S. L. Cai Institute of Mechanics, Chinese Academy of Sciences Email: caisonglin@lnm.imech.ac.cn

Abstract

Two-sphere collision (TSC) as a kind of fundamental impact phenomena is of both science and engineering significance. The classic theories based on Hertz contact mechanics work well for TSC at low speeds, but fail to describe high-speed behaviors with damages such cracks and debris. In this work, with TSC experiments and simulations, we measure two key parameters: the elastic restitution coefficient and momentum transfer factor with the relative collision speed up to 1000 m/s. We further perform the dimension analysis to obtain the scaling laws for the restitution coefficient and momentum transfer factor. It reveals that the relative speed and the speed ratio of TSC respectively dominate the elastic restitution and momentum transfer. Compared to the previous model, the TSC scaling laws show a better prediction of both experimental and simulation data. This work increases the understanding of TSC mechanism at high speeds.

Abstract Title	A novel impact fatigue testing machine based on electromagnetic technology
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Lubin Huo[1], Zengqiang Cao[1, 2] [1]Northwestern Polytechnical University [2]NPU Xu Hang Electromagnetic Technology Limited Company Email: l.huo@nwpu.edu.cn

Abstract

The impact fatigue problem of structures exists extensively in the aeronautical engineering field, and the catapult take-off and blocking of carrier-based aircraft are typical instances subjected to repeated impact loads. It is of great significance to study the problem of impact fatigue for engineering safety and economic cost saving. The impact fatigue testing machine is a key equipment for the impact fatigue investigations. However, the current impact fatigue test equipment generally adopts a motor to drive the cam to rotate to realize repeated impacts, and there are problems such as difficulty in adjusting the impact energy, small impact frequency and adjustable range, and the inability to change the shock waveform, which significantly restricts the progress of the impact fatigue research. To overcome these issues, the present study proposes an impact fatigue test equipment. The test bench fixed bracket of the equipment is successively provided with a striking rod, a first driving coil, a secondary coil and a second driving coil on one side of the test bench fixed support. A specimen fixed frame is arranged on the other side of the test bench fixed bracket. The H-bridge current commutator is connected with the first driving coil and the second driving coil. The H-bridge current commutator is used for changing the magnetic pole direction of the first driving coil and the second driving coil by controlling the current direction of the first driving coil and the second driving coil, so that the secondary coil produces motion under the action of magnetic field force to achieve repeated impacts. The control system is connected with the H-bridge current commutator, and the control system is used to set the parameters, and control the H-bridge current commutator conduction, turn-off time, and measurement of the number of impacts and impact energy according to the parameters. The novel impact fatigue test machine can realize high-precision control of impact energy magnitude, impact frequency adjustment, and shock waveform through magnetic field force adjustment.

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Abstract Title	Investigating High-Temperature and High-Strain-Rate Effects on Damage Growth and Fracture in Taylor Rod Impact for IS2062: 2006 GR E410W A Steel
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Manoj Kumar[1], P M Dixit[2] [1] Dr. B. R. Ambedkar National Institute of Technology Jalandhar [2] Emeritus Professor, Indian Institute of Technology Kanpur Email: kumarm@nitj.ac.in

Abstract

This study examines the combined effects of high temperature and high strain rate on damage growth and fracture patterns in Taylor rod impact problems, specifically for IS2062: 2006 GR E410W A steel. To investigate these influences, experiments are conducted under controlled conditions. Thermal chamber testing at four elevated temperatures evaluates the progression of damage under high-temperature environments. Simultaneously, dynamic loading conditions are studied through experiments at various strain levels up to fracture using a Tensile Split Hopkinson Pressure Bar (TSHPB) at three elevated strain rates to measure void growth.

Traditional simulations of Taylor rod fractures have often utilized damage growth laws based on continuum damage mechanics or similar models with critical damage criteria. However, these approaches do not adequately account for the effects of high-temperature and high-strain-rate conditions that are critical in such impact scenarios.

To address this gap, a novel damage growth law incorporating these extreme conditions is developed and implemented into the finite element software ABAQUS/Explicit via a user-defined material subroutine (VUMAT). This allows for precise simulations of stress and strain distributions, fracture initiation using a critical damage criterion, and tracking of fracture progression.

The results provide valuable insights into fracture mechanisms under extreme conditions, advancing the accuracy of numerical simulations for dynamic impact applications and informing material design and structural integrity assessments.

Experimental and numerical study on the penetration resistance of explosive welded A7075/A1060/TC4 composite plate

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Abstract: This study used explosive welding technology to manufacture 3mm+2mm+3mm A7075/A1060/TC4 composite plates. The interface between the upper and lower interfaces of the composite plate presents a straight and wavy structure, with no obvious microscopic defects. Through tensile shear and three-point bending tests, the tensile strength of the bonding interface was measured to be greater than 65 MPa. The fracture interface was pulled apart along the interior of the A1060 interlayer, and the ultimate strength under bending load was 1128 MPa. High speed penetration test of aluminum bullet on explosion welded A7075/A1060/TC4 composite target plate. The experiment utilized Two-stage light-gas gun to accelerate the projectile to 300 m/s, 600 m/s, 750 m/s, and 1000 m/s for impact testing on the composite plate, resulting in four different failure modes. The experiment shows that the impact resistance velocity of A7075/A1060/TC4 composite plate is between 600~750 m/s. For low-speed impact (300 m/s), only bullet marks are left on the impacted target surface (TC4 side); At a speed of 600 m/s, the aluminum projectile undergoes severe compression deformation and leaves pits on the target surface; When the speed increases to 750 m/s, the composite target plate experiences significant uplift and fragmentation; When the speed increases to 1000 m/s, the composite plate appears to be penetrated by the projectile. The experiment found that the back of the target plate (A7075 side) exhibited greater cracking deformation during high-speed impact compared to the impact target surface (TC4 side). Especially, even after the projectile penetrates, the welding interface still maintains a good bond.

Keyword: Explosive welding; Two-stage light-gas gun; High speed penetration; failure mode;

Abstract Title	Mechanical behavior and damage mechanism analysis of sustainable concrete
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Abstract

The development of high-performance sustainable concrete is a continuous goal in the field of civil engineering. In this study, we investigated a type of sustainable lightweight aggregate concrete, focusing on its dynamic mechanical behavior and damage mechanisms through experimental research and numerical simulation modeling. We proposed a novel fissure-type filling method for generating artificial spherical aggregates and developed a three-phase mesoscale simulation model incorporating aggregates, mortar, and the interfacial transition zone. Both simulations and experiments revealed the occurrence of conical failure phenomena around the interfacial transition zone of spherical artificial lightweight aggregates. Experimental results showed that the microporous structure of the artificial lightweight aggregates could not only attenuate stress waves but also absorb harmful air introduced by recycled rubber particles. With artificial lightweight aggregates and rubber particles mixed in appropriate proportions, the dynamic specific strength and energy absorption of the concrete were found to be 3% and 6% higher, respectively, than those of ordinary concrete. The agreement between simulation and experimental results validates the findings, providing valuable references for the design and application of sustainable concrete, particularly in impact-resistant applications.

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Abstract Title	Research on multi-directional gear walk characteristics of the aircraft dual-wheel main landing gear
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Qiaozhi Yin[1,3], Songyang Zhang[3], Jian Deng[2,4], Xiaohui Wei[2,3], Hong Nie[1,3] [1]National Key Laboratory of Rotorcraft Dynamics, Nanjing University of Aeronautics and Astronautics [2]State Key Laboratory of Mechanics and Control for Aerospace Structures, Nanjing University of Aeronautics and Astronautics [3]Key Laboratory of Fundamental Science for National Defense-Advanced Design Technology of Flight Vehicle, Nanjing University of Aeronautics and Astronautics [4]MIIT Key Laboratory of Multifunctional Lightweight Materials and Structures, College of Aerospace Engineering Email: yinqiaozhi@nuaa.edu.cn

Abstract

In the process of aircraft braking, the dual-wheel main landing gear is affected by the combination of the braking torque and the ground adhesion torque, resulting in gear walk. And the asymmetric braking torque could induce the multi-directional gear walk (longitudinal, lateral and torsional gear walk). In this study, the coupling mechanism and vibration characteristics of multi-directional gear walk are revealed. A rigid-flexible coupling dynamic model of dual-wheel main landing gear is established in Simcenter 3D by using component mode synthesis method, the main load components such as outer cylinder, side strut, torque link and piston rod are flexible body. The shock absorber model is built between the piston rod and the outer cylinder, which is mainly composed of air spring force, oil damping force and structural limiting force. The basic tire module in Simcenter 3D, which is used to build the tire model, can calculate the longitudinal force, lateral force and vertical force of the tire in the braking process according to the physical parameters of tire vertical stiffness, vertical damping, cornering stiffness and longitudinal friction coefficient. The brake control system model is established in MATLAB/Simulink to implement the asymmetric braking state. Then the collaborative simulation method is used to research the multi-directional gear walk characteristics and the multi-directional gear walk phase space is used to decouple multi-directional gear walk and reveal the coupling mechanism of multi-directional gear walk. The results show that the multi-direction gear walk is mainly composed of three kinds of vibration with different frequencies. Under the action of shock absorber, multi-directional gear walk phase space curve can form a stable periodic change region. When the difference of braking torque increases, the amplitude of multi-direction gear walk displacement, acceleration and load increase, the

longitudinal gear walk intensifies, causes torsional and lateral gear walk, and then makes the multi-direction gear walk coupling and intensifies.

Abstract Title	Releasing Energy Behavior and Deformation Mechanism in Energetic High-Entropy Alloys upon Impact Loading
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zhong Wang[1,2], Zhiming Jiao[1,2,*], Jie Zhang[1,2,3], Junwei Qiao[4], Zhihua Wang[1,2,**] [1] Institute of Applied Mechanics, College of Aeronautics and Astronautics, Taiyuan University of Technology, Taiyuan 030024, China [2] Shanxi Key Laboratory of Material Strength & Structural Impact, Taiyuan University of Technology, Taiyuan 030024, China [3] Department of Civil and Environmental Engineering, National University of Singapore, 117576, Singapore [4] College of Materials Science and Engineering, Taiyuan University of Technology, Taiyuan 030024, China Email: zhongwangty@hotmail.com; jiaozhiming@tyut.edu.cn

Abstract

Energetic materials exhibit high strength, high density, and excellent energy characteristics. Such alloys keep stable under routine conditions, while releasing abundant energy instantaneously upon impact loading. Kinetic energy coupled with chemical energy enhances the damage effect once the energetic materials are activated. In the current study, the energetic high-entropy alloys with high strength, good toughness, high density, and outstanding releasing energy characteristics were developed. The evolution of shear bands at high strain rates is fully investigated to explore the mechanism of ductile to brittle transition, which provides significant theoretical basis for the energetic high-entropy alloys in the potential application of penetration and explosion.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Study on the deformation and failure behavior of flat-nosed TC4 titanium alloy projectiles impacting steel target
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yue Zhou, Xinxin Zhao, Longlong Wang, Wenbo Zhuang, Zhe Chu, Mingshi Wang [1] Xi'an Jiaotong University Email: zy2021@stu.xjtu.edu.cn

Abstract

Ti–6Al–4V (TC4) alloy has garnered considerable attention in recent years for applications in warhead casings, owing to its high strength-to-weight ratio for a higher charge-to-casing mass ratio. This study investigates the dynamic behavior of flat-nosed TC4 alloy projectiles penetrating Q235 steel targets at impact velocities of 800 m/s, 983 m/s, and 1167 m/s, focusing on adiabatic shear band (ASB) evolution and its influence on projectile morphology and failure mechanisms. Experimental results indicate that at 800 m/s, the projectile fails to penetrate the target, exhibiting severe plastic deformation and a mushroom-shaped nose of abundant adiabatic shear bands (ASBs) with micro-voids and cracks. At 983 m/s, the projectile demonstrates a self-sharpening behavior due to material spalling, resulting in a reduced number of ASBs and successful penetration. At 1167 m/s, the self-sharpening effect is more pronounced, with minimal ASBs observed. Numerical simulations validate the experimental results and are further employed to explore a wider spectrum of impact conditions.

Abstract Title	Effect of target structural stiffness on projectile fracture during penetration of ultra-high-strength steel plates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Peng Chen, Yuyao Gao, Wenbo Zhuang, Zhe Chu, Mingshi Wang [1] Xi'an Jiaotong University Email: pchen@stu.xjtu.edu.cn

Abstract

Ultra-high-strength steels have garnered considerable attention in recent years due to their potential for applications in protective structures. This study investigates the dynamic behavior of blunt 30CrMnSiNi2MoVE steel projectiles penetrating ultra-high-strength steel plates of varying thicknesses at an impact velocity of 400 m/s, focusing on penetration resistance and projectile fragmentation mechanisms. Numerical simulations show that the projectile perforates the 10 mm and 12 mm plates, exhibiting plastic deformation at the nose. However, when the plate thickness increases to 15 mm, the projectile fails to penetrate the target and fractures upon impact. This behavior is attributed to the increased structural stiffness associated with greater thickness, which reduces the energy absorption of the target and increases the energy transferred into the projectile, ultimately causing its failure. To decouple the effects of thickness and structural stiffness, simulations are further conducted on 10 mm and 12 mm plates backed by concrete blocks. These configurations prevent penetration and induce projectile fragmentation. These findings offer valuable insights into the design of advanced protective structures using ultra-high-strength steel.

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Abstract Title	GISSMO Damage Model-Based Analysis of Impact Failure in Aluminum Alloy MEGA Casting Front Compartment
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Changlei Zhang[1], Jian Yang[1], Kangle Wang[1], Bo Liu[1] [1] University of Science and Technology Beijing Email: liubo1@ustb.edu.cn

Abstract

This study focuses on the impact failure behavior of an integrated die-cast aluminum alloy front cabin structure, with cast aluminum C611 as the research subject, conducting systematic research on the establishment and validation of its GISSMO (Generalized Incremental Stress State Dependent Damage Model) damage model. Through quasi-static and dynamic mechanical tests, fracture strain data of the material under different strain rates and stress states were obtained. Combined with stress triaxiality analysis, the GISSMO failure model for cast aluminum C611 was established, with damage accumulation index and stress degradation parameters determined. Validation through drop hammer impact tests and simulation comparisons demonstrated that the model achieves less than 5% error in predicting impact force peaks, while the predicted failure patterns showed good agreement with experimental observations. The results confirm that the developed GISSMO damage model can accurately characterize the damage and fracture behavior of cast aluminum C611 under complex stress states, providing a reliable theoretical basis for crashworthiness design of automotive front cabin structures.

Abstract Title	Double-stage Gear Cluster-Enabled Metastructure for Ultra-wide Range Continuously Tunable Stiffness
List of authors & their affiliations with the presenter's name underlined . Provide email contact for the presenter.	Bingren Wang Yiru Ren Hunan University Email:wangbingren@hnu.edu.cn

Abstract

The superior mechanical properties and lightweight characteristics of lattice structures enable effective mitigation of water impact-induced structural damage in transmedia vehicles. Due to the hydroelastic effect, the modal response of lattice structures under water impact compared to rigid impacts significantly. In this study, we classify different groups of lattices based on their topology and propose a strategy to enhance their energy absorption-to-weight ratio under compression. Experimental compression tests and numerical data obtained through finite element analysis demonstrate that a uniform design, with an even distribution of relative density, yields the highest initial stiffness among all 3D-printed architected lattices. However, a graded design, which incorporates a rational variation of relative density, can significantly enhance both stiffness and energy absorption capacity in lattices subjected to high compressive strains. Based on the coupled FEM-SPH method, we investigate the down-loading characteristics of multi-class graded lattices under water-entry impacts at speeds of 5 m/s, 8 m/s, and 10 m/s. Specific gradients, where relative density varies perpendicularly to the direction of external compressive forces, can increase the energy absorption capabilities of cellular solids by up to 20% and 80%, respectively. These findings suggest the potential for designing single-phase lattice architectures that combine lightweight and energy absorption properties under water impact through a rational variation of porosity within lattice structure.

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Date: 16th - 18th July 2025
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Abstract Title	Dynamic fracture analysis of multi-interface piezoelectric composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Shuai Zhu[1], Zhiyong Wang[1], Hongjun Yu[2] [1]Taiyuan University of Technology [2]Harbin Institute of Technology Email: zhushuai@tyut.edu.cn

Abstract

Dynamic intensity factors (IFs) are the key parameters in comprehending and forecasting dynamic fracture behavior of piezoelectric composites. A domain-independent interaction integral (DII-integral) is developed to extract the dynamic stress intensity factors and electric displacement intensity factor. The DII-integral is theoretically proved that there is no need to consider the electromechanical material derivatives and complicated material interfaces have no effect on the application of the method. Evaluating the results with the published data yields a good agreement and good domain-independence of the proposed I-integral is checked for multi-interface piezoelectric composites. The numerical simulations show that the amplitudes of the dynamic IFs decrease as the size of piezoelectric particle increases and crack damage is prevented as the number of piezoelectric particles increases. The peak values of the dynamic IFs are not monotonically related to the distance between the particles due to the superposition of elastic waves. Generally, the dynamic IFs increase when the volume percentage of piezoelectric fiber rises, while the opposite change is observed in laminated composites. Recently, the DII-integral are successfully extended to the dynamic fracture analysis of piezoelectric/piezomagnetic composites and good computational results exhibit the broad application of the dynamic DII-integral for more emerging functional materials in the future.

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Abstract Title	Energy partitioning of crack propagation in rock: a peridynamics study
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xu Li[1], Daniel Dias-da-Costa[1], Luming Shen[1] [1]School of Civil Engineering, The University of Sydney, NSW 2006, Australia Email: xu.li2@sydney.edu.au

Abstract

During the extremely short period of rock crack propagation, the energy flux at the crack tip is distributed among various dissipation mechanisms, including fracture energy, acoustic energy, kinetic energy, and heat energy. Laboratory measurements of all these dissipation mechanisms based on a single experiment are challenging, and therefore numerical approaches can play an important role in assessing the energy budget during crack propagation. In this study, nonlocal peridynamics (PD) is applied to formulate energy dissipation in rock cracking. A damage variable is used to represent bond breakage between particles in the PD models, as well as to describe the macroscopic crack propagation. The fracture energy is then calculated based on the bond breakage. The acoustic radiation energy and kinetic energy are determined by tracking the global particle positions. As a result of this research, the plastic and residual elastic energies are identified as also accounting for a significant percentage of overall input energy of crack propagation. Overall, this study provides new insights into the determination of energy dissipation mechanisms during crack propagation in rock.

MS8- Impact induced damage and fracture behavior of materials at micro-/nano-scale

Abstract Title	Scaling law for impact resistance of amorphous alloys connecting atomistic molecular dynamics with macroscale experiments
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xianqian Wu[1], Chenguang Huang[1], William A. Goddard III[2] [1] Institute of Mechanics, Chinese Academy of Sciences [2] California Institute of Technology Email: wuxianqian@imech.ac.cn
Abstract	

Establishing scaling laws for amorphous alloys is of critical importance for describing their mechanical behavior at different size scales. In this paper, we derive the scaling law for Ni2Ta amorphous metallic alloy as a prototype materials system. We use laser-induced supersonic micro-ballistic impact experiments to measure for the first time the size-dependent impact response of amorphous alloys. We also report results from Molecular Dynamics (MD) simulations of the same system but at much smaller scales. Comparing these results, we determined a law for scaling both length and time scales based on dimensional analysis. This connects the time and length scales of the experimental results on the impact resistance of amorphous alloys to that of the MD simulations. We use this comparison to provide a method for bridging the gap in comparing the dynamic behavior of amorphous alloy materials at various scales with aim of providing a guideline for fabrication of new amorphous alloy materials with extraordinary impact resistance.

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Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	A dynamic strain gradient brittle fracture model based the two-scale asymptotic expansion theory
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Meizhen Xiang[1], Yipeng Rao[2], Quanzhang Li[1,3], Junzhi Cui[3] [1] Institute of Applied Physics and Computational Mathematics [2] PKU-Changsha Institute for Computing and Digital Economy [3] LSEC, ICMSEC, Academy of Mathematics and Systems Sciences, CAS, China Email: xiang_meizhen@iapcm.ac.cn

Abstract

Microstructure, strain gradient and strain rate are key factors that influence dynamic fracture of heterogeneous brittle materials. We develop an analytical dynamic fracture criterion by using an two-scale asymptotic expansion theory accounting for micro-inertia. The formulation for microscopic dynamic energy release rate involving additive contributions of macroscopic strain, strain gradient and strain rate. The coefficients of the formulation are correlated to microstructural length scale and are calculated based on integrals of the first order microscopic cell solutions. The two-scale formulation of energy release rate, along with the Griffith law for a single microcrack, results in a novel dynamic fracture model. The remarkable feature of this modeling approach is that, without extra phenomenological ad hoc hypotheses, all microstructural length scale, strain gradient and strain rate effects are natural consequences of the unified two-scale theory.

Abstract Title	Micro-ballistic impact of a $Co_{33}Os_{20}Ta_{10}B_{37}$ metallic glass with ultrahigh dynamic strength
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	G. Ding[1], M.Q. Jiang[1,2] [1]State Key Laboratory of Nonlinear Mechanics, Institute of Mechanics, Chinese Academy of Sciences, Beijing 100190, China [2]School of Engineering Science, University of Chinese Academy of Sciences, Beijing 100049, China Email: dinggan@lnm.imech.ac.cn

Abstract

Metallic glasses (MGs) show significant potential for hypervelocity impact protection due to their high hardness and dynamic strength. In this study, the protective performance of a new $Co_{33}Os_{20}Ta_{10}B_{37}$ MG was systematically evaluated. Plate impact experiments revealed an ultra-high Hugoniot elastic limit (HEL) up to 19 GPa, setting a new record for metallic materials. Using the laser-induced micro-particle impact test (LIPIT), we characterized the impact response and protective performance of $Co_{33}Os_{20}Ta_{10}B_{37}$ subjected to SiO_2 micro-particle impact. The results demonstrated a high coefficient of restitution (COR) and dynamic strength for $Co_{33}Os_{20}Ta_{10}B_{37}$. More importantly, the low impact-mode ratio further indicates that it can efficiently withstand the high-velocity impact of micro-particles, as confirmed by the absence of craters in post-impact surface. These results emphasize the outstanding resistance of $Co_{33}Os_{20}Ta_{10}B_{37}$ MG to hypervelocity impact, underscoring its promising potential as an advanced protective material.

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	Ultrahigh dynamic strength and graphene-level impact resistance achieved in a crystal-glass nanostructured Al alloy
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hongbo Zhou[1], Minqiang Jiang[1] [1]Institute of Mechanics, Chinese Academy of Sciences Email: zhouhb@imech.ac.cn

Abstract

High dynamic strength and impact resistance are essential for materials used in high-strain-rate environments. Metallic materials, while widely utilized, often underperform compared to carbon-based materials with superior strength or polymers with exceptional deformability. Here, we present an aluminum alloy with ultrahigh dynamic strength and graphene-level impact resistance, enabled by the delicate design of a crystal-glass nano-heterostructure that synergistically integrates crystalline and amorphous phases. The alloy's remarkable dynamic strength is attributed to the extreme refinement of structural units composed of both phases. In addition, its outstanding impact resistance arises from the combined effects of ultrahigh strength, efficient delocalization of impact energy, and a crystalline-to-amorphous phase transformation under high-speed loading. This crystal-glass nano-heterostructured design provides a promising pathway for the development of advanced materials capable of serving in extreme mechanical environments.

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Date: 16th - 18th July 2025
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Abstract Title	Energy absorption and plastic deformation of random bit-continuous nanoporous metallic glass under shock loading
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	W.X. Tang[1], L.X. Feng[1], Z.C. Chen[1], W.H. Li[2], X.C. Tang[1], L.Y. Meng[1], X.H. Yao[1]. [1]Department of Engineering Mechanics, South China University of Technology, Guangzhou, Guangdong, 510640, China [2]Institute of High-Performance Computing (IHPC), Agency for Science, Technology and Research (A*STAR), 1 Fusionopolis Way,#16-16 Connexis, 138632, Singapore Email: 2370072240@qq.com

Abstract

Nanoporous metallic glass (NPMG) uniquely integrates the advantageous properties of metallic glass with a porous architecture, resulting in a novel material characterized by lightweight, high plasticity, and substantial energy absorption capacity. These features present significant potential for applications in armor-piercing resistance and shockwave mitigation. However, the intricate structure and the extremely small time and spatial scales involved render the quantitative understanding of its energy absorption mechanisms and the influence of structural parameters on energy absorption still ambiguous. This study employs non-equilibrium molecular dynamics simulations to investigate the impact compression process of random bit-continuous NPMG. The findings indicate that energy absorption during the initial stage of compression is predominantly due to structural deformation, transitioning to thermal energy accumulation in the later stages. Analysis of varying shock velocities reveals that at low velocities, energy absorption is governed by a velocity mismatch shear mode, while at high velocities, a coupled boundary unloading deformation mode emerges, resulting in an increase in structural deformation energy absorption with higher impact velocities. Additionally, the solid ratio of the structure exerts a multifaceted influence on impact energy absorption. An increase in the solid ratio transitions structural deformation from a single to a coupled mode, thereby enhancing energy absorption efficiency. Meanwhile, this increase also accelerates structural compaction, leading to a reduction in energy absorption time per unit volume. Another structure parameter, ligament diameter, it's increase mainly leads to an increase in the difficulty of boundary unloading deformation and a decrease in the deformable area of the surface.

Abstract Title	In-situ scanning electron microscopy analysis of creep-induced damage behavior of initial pores in nickel based single crystal superalloy
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Ziyuan Song[1], Dawei Huang[1], Yanxiao Jun[1] [1]Beihang University Email: 14041120@buaa.edu.cn

Abstract

Pores are widely present in the interdendritic regions of single-crystal superalloys and cannot be eliminated during the directional solidification process used to remove grain boundaries. Such initial pores can cause stress concentration and damage accumulation in the surrounding area under creep conditions. Previous studies on the damage behavior of pores have focused on the geometric dimensions of the pores, such as volume fraction and the size of individual pores, with less attention paid to the damage mechanisms of pores.

In this study, the evolution of damage around initial pores in single crystal superalloy under creep conditions and their contribution to macroscopic fracture are investigated. Using in-situ scanning electron microscopy testing, the creep behavior of nickel based single crystal superalloys under 980°C/500MPa with the primary orientations [001] and [100] was studied. Under this experimental conditions, the initial pores gradually elongate and develop into square microcracks along the tensile direction as the experiment progresses. These microcracks do not close upon unloading. HR-DIC indicates that cracks generated by initial internal pore may form two strain concentration zones on the surface with gradually decreasing spacing during the process of crack propagation from the interior to the surface. The nucleation of microcracks at the edges of pores are studied by prefabricating pores on the surface and conducting in-situ experiment. Fractography analysis indicates that the different distribution patterns of cracks caused by internal initial voids may be the reason for the lifespan differences between the [001] and [100] orientations.

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Abstract Title	Numerical simulation on the damage mechanism of TATB-F2314 polymer interface
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Li Lv[1], Jun Chen[1] [1]Institute of Applied Physics and Computational Mathematics, Beijing, China Email: Jun_chen@iapcm.ac.cn

Abstract

The microstructure characteristics, mechanical properties, interface plastic deformation and damage failure mechanism of explosive crystal-binder interface are of great significance to the design, preparation and safe application of PBX explosive. It has been difficult to study the micromechanical behavior of the PBX explosive interface because of the complexity of the interface and the sensitivity of the explosive crystal itself. In this talk, we will repot some results on the microstructure, elastic-plastic deformation, debonding failure and mechanical properties of TATB-F2314 polymer bonded explosive interface at the atomistic level by using molecular dynamics simulations. It is revealed that an intermixing phase exists between TATB and F2314, and the formation of the intermixing phase is related to the distortion and deformation of TATB layers. Interatomic interactions different from those in TATB or F2314, such as hydrogen bonds and strong van der Waals forces, are found in the intermixing phase, which promote the combination of TATB and F2314 and enhance the interfacial interaction. Further, the nano-indentation numerical test of PBX explosive is conducted to study the damage behaviors, the effect of interface strength and the thickness of the intermixing phase were investigated. The discovery of the intermixing phase gave us a further understanding about the microstructure of the TATB-F2314 interface.

Abstract Title	FCC-BCC-Amorphization Hierarchical Phase Transformation Induced Synergy Enhancement of Strength and Ductility of Nanolamellar High Entropy Alloy at High Strain Rate
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Wanghui Li[1], Shuai Chen[2], Shiteng Zhao[3], Yilun Xu[1], Yingzhi Zeng[1], Zachary Aiken[1], Hugh, Short[4], Zhigen Yu[1], Kewu Bai[1], Guglielmo Vastola[1], David J. Srolovitz[5], Peter K. Liaw[4], Yong-Wei Zhang[1] [1] Institute of High-Performance Computing (IHPC), Agency for Science, Technology and Research (A∗STAR), 1 Fusionopolis Way,#16-16 Connexis, Singapore 138632 Singapore, Republic of Singapore [2] Materials Genome Institute, Shanghai University, Shanghai 200444, China [3] School of Materials Science and Engineering, Beihang University, Beijing, China [4] Department of Materials Science and Engineering, The University of Tennessee, Knoxville, TN, 37996, United States [5] Department of Mechanical Engineering, The University of Hong Kong, Hong Kong SAR, China Email: li_wanghui@ihpc.a-star.edu.sg

Abstract

Developing advanced structural materials for extreme environments is increasingly urgent for next-generation technological applications in aerospace, transportation, and energy sectors. The demanding environments require materials with high strength and ductility and even lightweight. To overcome the long-standing strength-ductility trade off challenges, different heterogeneous nanostructures have been proposed. Here we identify a FCC-BCC-Amorphization hierarchical phase transformation induced synergy enhancement of spall strength and ductility of Nanolamellar AlxCoCuFeNi high entropy alloys at extremely high strain-rates through a series of large-scale molecular dynamic simulations. The effects of nanolayer thickness and crystal orientation as well as strain rate on the spall strength are systematically revealed. A design strategy for a nano-lamellar with enhanced performance is accordingly proposed.

The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Spallation of several random alloys by nonequilibrium large-scale molecular dynamic simulations
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Kun Wang Hunan University Email: wangk@hnu.edu.cn

Abstract

Random alloys are widely used in various technical fields and exhibit great potential in aspects such as high strength and toughness. One of the most well-known examples is high-entropy alloys. However, current understanding of the dynamic mechanical properties of these materials is still insufficient, especially regarding the mechanisms at the atomic level. This work focuses on CoCrCuFeNi high-entropy alloy and U-Nb random alloy. Using large-scale nonequilibrium molecular dynamics methods, the grain boundary segregation behavior of random high-entropy alloys, the lattice distortion induced by solutes, and their effects on dynamic fracture behavior are systematically studied. For the U-Nb alloy system, this work delves into the evolution of the U-Nb alloy structure with composition changes and atomic mechanisms from the perspective of interatomic interactions, revealing the microscopic mechanisms behind the disappearance of elastic precursors, as well as the formation mechanism of deformation twins and spallation response behaviors upon dynamic loadings. This work would contribute to deepen the current understanding of the dynamic mechanical properties of random alloys for purposes of guiding material production and processing.

The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Revealing the fracture mechanism of HfNbTaTiZr refractory high-entropy alloy by X-ray tomography
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hong Chen[1], Ruitao Qu[1], Haotian Ma[1], Shaogang Wang[2], Feng Liu [1] Northwestern Polytechnical University, China [2] Institute of Metal Research, Chinese Academy of Sciences Email: rtqu@nwpu.edu.cn

Abstract

The HfNbTaTiZr refractory high-entropy alloy (RHEA), characterized by a single-phase body-centered cubic (BCC) structure, exhibits excellent high-temperature properties. Notably, its room-temperature fracture toughness is remarkably high [see Fan et al., J. Mater. Sci. Technol. 123 (2022) 70-77], comparable to that of the tough face-centered cubic (FCC) Cantor alloy. However, its tensile strength and uniform elongation are relatively less impressive. To elucidate the underlying mechanisms responsible for its high fracture resistance, we conducted quasi-in situ tensile tests and characterized the damage evolution using three-dimensional X-ray tomography. Our findings revealed that voids within the alloy grow very slowly, particularly during the later stages of the tensile process, which is significantly different from the predictions of the classical void-growth model applicable to traditional alloys such as steel. Further results suggest that the ductile fracture behaviour of the RHEA can be well described by the traditional Gurson-Tvergaard-Needleman (GTN) model, albeit with notably smaller critical void volumes for failure. The slow void growth and coalescence processes, which may originate from suppressed dislocation emission in the RHEA, contribute to its large non-uniform elongation and high fracture resistance. These results provide new insights into the high toughness of the HfNbTaTiZr RHEA and may aid in understanding the unique fracture mechanisms in ductile RHEAs.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	Impacting fracture behaviors of MXene-based thin film
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Abstract

In this work, one kind of novel MXene-based super-thin film was prepared. The impact fracture behaviors of such film were investigated by an advanced testing technique at micro-nano scale for the first time, by which two different fracture behaviors were revealed with different impacting velocities. Then, the corresponding fracture mechanisms were studied by the molecular dynamics simulation. This work provides experimental and theoretical insights into cracking propagation of film structure assembled by two-dimensional nanomaterials.

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Venue: National University of Singapore

Abstract Title	Scaling law of launch velocity in laser-induced microparticle impact testing
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zhoupeng Gu[1], Yiping Song[2, 3], Minqiang Jiang[4], Qiuyun Yin[1], Chenguang Huang[1, 2], and Xianqian Wu[1, *] [1] Key Laboratory of Mechanics in Fluid Solid Coupling Systems, Institute of Mechanics, Chinese Academy of Sciences [2] Anhui Institute of Optics and Fine Mechanics, Hefei Institutes of Physical Science, Chinese Academy of Sciences [3] University of Science and Technology of China [4] State Key Laboratory of Nonlinear Mechanics, Institute of Mechanics, Chinese Academy of Sciences Email: guzhoupeng@imech.ac.cn *Corresponding author

Abstract

Laser-induced microparticle impact testing (LIPIT) is a useful method for measuring the dynamic mechanical behavior of materials under ultra-high strain rates by accelerating and launching single microparticle at high velocity. It is of importance to establish a scaling law for the laser-induced microparticle launching system to optimize its configurations and improve the achievable velocity of the microparticle. In this study, the physical process of laser-induced microparticle launching is analyzed. A scaling law for the launch system is obtained by dimensional analysis. The influence of dominant dimensionless parameters on the dimensionless velocity of microparticles is then assessed by numerical simulations. The results show that the dimensionless launch velocity of the microparticle increases with increasing the dimensionless energy and dimensionless time of the laser pulse and with decreasing the dimensionless thickness of metal and elastomer films and the dimensionless mass of microparticle. Finally, the dimensionless formulas for predicting the velocity of the microparticle of the launch system with thick-metal-film and thin-metal-film configurations are determined, respectively. This study promotes the understanding of the launch mechanisms of LIPIT and provides a guideline for optimizing its configurations to achieve a wide range of impact velocities of the microparticles.

Keywords: Laser-induced microparticle impact testing; scaling law; launch velocity; dimensional analysis; numerical simulation.

Abstract Title	Damage and failure behavior of single fibers under transverse impact
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xudong Lei[1,2], Xianqian Wu[1,2] [1] Institute of Mechanics, Chinese Academy of Sciences, Beijing 100190, China. [2] School of Engineering Science, University of Chinese Academy of Sciences, Beijing 100049, China. Email: leixudong@imech.ac.cn

Abstract

Obtaining the damage and failure behavior of single fibers under transverse impact is critical for understanding the protective behavior of fiber-reinforced composites. In this study, laser-induced particle impact tests were used to launch individual particles to rupture a finite-length single fiber, enabling the calculation of the fiber's specific penetration energy by evaluating the difference in kinetic energy before and after particle impact, along with the fiber's linear density. The dynamic enhancement effect of the fiber is evaluated by analyzing the ratio of its energy absorption to tensile strain energy. The results show that polymer fibers suffer a certain degree of damage during transverse impact, preventing the full utilization of the fiber's dynamic tensile strain energy. In contrast, carbon nanotube fibers demonstrate a significant dynamic enhancement effect, attributed to the high transverse mechanical properties of the internal carbon nanotubes. This study provides a foundation for evaluating the protective performance of single fibers.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Spatial scale effect and statistical characteristics of cavitation in liquid aluminum: MD simulation and modeling analysis
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Dong-Dong Jiang[1], Jian-Li Shao[1] [1] Beijing Institute of Technology Email: jiangdd@mail.ustc.edu.cn

Abstract

Microscopic simulation methods, particularly molecular dynamics (MD) simulations, have long been essential tools for studying material damage and fracture behavior. The effects of strain rate and size on material damage processes are key areas of research. However, much of the current research on size effects focuses on the material microstructure, studies on the impact of system spatial size remain limited. To clarify the impact of system size on damage in microscopic simulations while excluding the influence of the initial microstructure, this study focuses on the cavitation behavior of liquid aluminum. A series of extensive MD simulations were conducted on systems of different sizes under varying strain rates. The results indicate that the dynamic tensile strength of liquid aluminum exhibits significant scale effects at the microscale: it initially decreases as system size increases, then stabilizes at larger sizes. This is accompanied by a change in the damage evolution mechanism, from random nucleation of isolated voids to a more statistically predictable behavior involving a higher number of voids, which also reduces the randomness in tensile strength. To further explore the observed trends, a microscopic theoretical model of cavitation in liquid aluminum, based on void nucleation and growth, is developed. This model accurately captures the size-dependent variation in dynamic tensile strength under varying strain rates and successfully predicts the strain rate dependence of dynamic tensile strength at the macroscopic scale, with results that align well with experimental observations.

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Abstract Title	Machine-learning informed atomistic mechanisms of hierarchical plastic deformations in high entropy (Zr0.2Hf0.2Ti0.2Nb0.2Ta0.2)C under shock loading
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Lanxi Feng[1,2], Wenxuan Tang[1], Zhuochen Chen[1], Xiaoqing Zhang[1], Guglielmo Vastola[4], Fu-Zhi Dai[3], Xiaohu Yao[1], Yong-Wei Zhang[4], Wanghui Li[4] [1]State Key Laboratory of Subtropical Building Science, South China University of Technology [2]National Key Laboratory of Shock Wave and Detonation Physics, Institute of Fluid Physics [3] School of Material Science and Engineering, University of Science and Technology Beijing [4]Institute of High Performance Computing (IHPC), Agency for Science, Technology and Research (A*STAR) Email: 657184861@qq.com

Abstract

Ceramics have ultra-high strength but are often brittle. How to improve the toughness of ceramics has long been a significant subject in both academia and industry. The introduction of the "high entropy effect" in high entropy carbide ceramics (HECCs), offers a new perspective to enhance the plasticity of these ceramics, which have a great potential for aerospace and protective applications under extreme conditions. However, there is a scarcity of research on the dynamic behavior of HECCs. Exploring their plastic behavior and understanding their response to dynamic loading is crucial for their practical applications. In this work, the dynamic behavior of a high-entropy ceramic $(Zr_{0.2}Hf_{0.2}Ti_{0.2}Nb_{0.2}Ta_{0.2})C$ (denoted as HEC) under shock compression is investigated by molecular dynamics simulations utilizing a deep learning potential based on accurate first-principles data. With increasing the particle velocity (Up), HEC undergoes a pronounced elastic-plastic transition characterized by the formation of multiple plastic deformation bands, local phase transition and amorphization, which involve the activations of <11 0>{1 1 0} and <11 0>{1 1 1} slip systems simultaneously. The local lattice distortions in HEC are found to influence the behavior of dislocation propagation during shock compression. Instead of following predefined paths, dislocations tend to deviate at the propagation front, resulting in the formation of vacancies. Our findings reveal the hierarchical plastic deformation capabilities of HEC under extreme conditions, suggesting a promising strategy for achieving HECCs that are both strong and ductile.

MS9- Damage characterization of advanced composite materials and structures

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Investigation on damage behavior of woven composites under high and low cycle fatigue loads
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Licheng Guo[1], Zhanguang Chen[1], Zhongyu Wang[1] [1] Harbin Institute of Technology Email: guolc@hit.edu.cn

Abstract

The fatigue damage behavior of fiber-reinforced woven composites is complex and has absorbed great attention in recent years. The present study investigates the damage mechanisms and failure behavior of the composites under combined high and low cycle fatigue (CCF) loading conditions. By integrating a multi-source damage information fusion approach (CT-IRT-DIC) with specially designed uniaxial and biaxial fatigue loading spectra, a comprehensive analysis is conducted on the variation of fatigue life, energy dissipation, strain field evolution, stiffness degradation and damage morphology during the fatigue process. The influence of the coupled interaction between high cycle fatigue (HCF) and low cycle fatigue (LCF) loading on damage accumulation and fatigue resistance of the fiber-reinforced composites is systematically revealed.

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Abstract Title	Strength prediction of composite bolted joints under hygro-thermal-mechanical coupling via progressive damage method
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Meijuan Shan[1], Yu Gong[2], Fengrui Liu[3], Libin Zhao[4] [1]Beijing Jiaotong University [2] Chongqing University [3] Beihang University [4] Hebei University of Technology Email: mjshan@bjtu.edu.cn

Abstract

Hygrothermal environment is considered to be one of the three major threats to safety of composite structures, because it significantly weakens load-bearing capacities of composite structures at multi-scale level. Composite bolted joints are weakness of composite structures. Therefore, its failure mechanism and strength prediction method under hygro-thermal-mechanical coupling are critical. Considering typical hygrothermal conditions of highly-loaded structures in large aircrafts, a progressive damage model considering hygrothermal effects was developed and used to reveal coupling influence of hygrothermal environment and geometric parameter on strength of joints. Besides, a characteristic curve equation considering hygrothermal effect was established, and further used to develop a numerical framework for predicting strength of multi-bolted composite joints. Experimental data of open-hole laminate, single-bolt joints, and multi-bolted joints were used to validate the proposed numerical method.

Abstract Title	Failure mechanism and multi-scale simulation of high-speed impact damage of 3D woven composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Bowen Wu[1], Chao Zhang[1] [1]Northwestern Polytechnical University Email: wbw2001@mail.nwpu.edu.cn

Abstract

Three-dimensional (3D) woven composites have become widely used in aerospace structures as a substitute for metal materials, due to their higher specific stiffness and strength compared to alloy materials, as well as better impact resistance than traditional laminate composites. A novel multi-scale modeling approach is proposed to efficiently predict the impact damage behavior of 3D woven composites. A theoretical-based multi-scale model is integrated with finite element calculation, as a user subroutine, VUMAT. The developed multi-scale model enables real-time two-way coupled interactions for mechanical response and damage behavior at meso- and macro-scales, and shows great computational efficiency and generality because of the theoretical nature of the multi-scale computational framework. The proposed framework is utilized to simulate the high-speed impact behavior of 3D woven composite panels. The predicted results show good agreement with both the meso-scale finite element simulations and the experimental results, while significantly reducing computational time compared to the meso-scale model. Overall, the proposed multi-scale modeling method proves its feasibility for impact analysis and design of 3D woven composite structures.

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Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Translaminar fracture of Double-Double composite laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xiang Li[1], Jie Zhi[1], Bin Yang[1] [1]Tongji University Email: lixiang_tj@tongji.edu.cn

Abstract

The advent of the double-double layup has simplified the design and manufacturing processes of composite materials, offering a promising solution for lightweight structures. Despite the advantages of the Double-Double (DD) layup, research on its mechanical properties remains limited. This study investigates the translaminar fracture behaviour of Double-Double composite laminates. A set of R-curves were measured for both traditional QUAD laminates (comprising 90°, 0°, and ±45° plies) and Double-Double laminates with $[\pm\Phi/\pm\Psi]_{nT}$ stacking sequences using two tapered compact tension (2TCT) specimens. The failure processes of the different laminates were observed using digital microscopy and X-ray imaging. This investigation can provide valuable insights into the fracture behavior of Double-Double laminates, which are crucial for advancing the design and optimization of lightweight, high-performance composite structures in aerospace and automotive applications.

Abstract Title	Multi-Scale Analysis of Low-Velocity Impact Resistance of Bionic Helicoidal Composite Laminates with void defect
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Chenxi Yang[1,2], Yiru Ren[1,2] [1]State Key Laboratory of Advanced Design and Manufacturing Technology for Vehicle, Hunan University, Changsha, Hunan 410082, China [2]College of Mechanical and Vehicle Engineering, Hunan University, Changsha, Hunan 410082, China Email: renyiru@hnu.edu.cn

Abstract

A multi-scale modeling approach was proposed to investigate the reinforcement mechanism of bionic helicoidal composite laminates (BHCL) under low-velocity impact and the effect of manufacturing-induced void defects. The Multi-scale Progressive Damage Model starts from microscale analysis, which established the microscopic constitutive relationship by the micro-scale mechanical parameters, and then the macroscopic effective properties are derived. The failure behavior of laminates is predicted after the establishment of the mapping relationship between micro-scales and macro-scales according to macroscopic stress. The micro-scale model was validated by the Chamis's model, and the macro-scale model by experiment results. The results indicate that BHCLs promote a uniform stress distribution across layers, significantly reducing delamination and fiber, matrix failure, thus improving impact resistance. Layers near the impact region with larger helical angles like sinusoidal arrangement exhibit more significant reinforcement. Increasing porosity in BHCLs leads to an overall decline in mechanical properties, with matrix-dependent characteristics like transverse tensile/compressive modulus and strength most affected. With the increase of voids, the matrix damage of RVEs increases, which leads to the fiber tensile fracture and matrix cracking of the laminates. Meanwhile, the helical structure can effectively reduce the influence of manufacturing defects on the low-velocity impact resistance of the laminates.

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Abstract Title	Damage-Tolerant Lightweight Design of Aerospace Structures: Prestress Optimization and Digital Twin Driven Approaches
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jiaming Guo[1,2], Houyang Li[1,2], Hongwei Liu[1,2], Changguo Wang*[1,2] [1] School of Astronautics, Harbin Institute of Technology, Harbin 150001, China [2] National Key Laboratory of Science and Technology on Advanced Composites in Special Environments, Harbin 150001, China Email: jmguo@hit.edu.cn

Abstract

This study addresses the extreme lightweighting requirements of aerospace vehicle structures, focusing on reducing launch costs and improving payload efficiency while systematically considering the influence of structural damage evolution on maneuverability and on-orbit lifespan. First, a damage tolerance assessment model for pre-stressed pressurized structures is established, analyzing their expansion deformation and buckling behavior while evaluating damage accumulation under cyclic loading, thereby revealing the relationship between pressurization parameters and structural damage thresholds. Second, a damage constitutive model is incorporated into the lightweight design of tensegrity structures, optimizing member layout through pre-stress field modulation to suppress crack initiation and propagation while maintaining load-bearing stiffness. Finally, a digital twin framework integrating damage evolution prediction is developed, combining topology optimization to achieve synergistic design of stress and damage fields, enabling extreme lightweighting under damage tolerance constraints. Numerical simulations based on damage mechanics demonstrate that the proposed method significantly enhances structural damage resistance, extending fatigue life by approximately 27% while maintaining high lightweight efficiency. This research provides a novel paradigm for aerospace structural design that harmonizes mechanical performance and damage evolution.

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Abstract Title	Off-axis mechanical behavior and dynamic characteristics of UHMWPE composite laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jian Deng[1], Guang Ran Shao[1], Qiao Zhi Yin[1], Jia Tao Zhao[1], Tian Jian Lu[1] [1]Nanjing University of Aeronautics and Astronautics Email: dengjian@nuaa.edu.cn

Abstract

An understanding of the off-axis mechanical behavior and failure mechanisms of ultra-high molecular weight polyethylene (UHMWPE) cross-ply laminates subjected to quasi-static and dynamic loadings is developed, with focus on the influence of off-axis angle and strain rate. For off-axis tension, UHMWPE laminates exhibit polymer shear response characteristics. An orientation-hardening phenomenon is captured, as fiber rotation leads to local increment of load capacity along the loading orientation. The failure strength presents an evidentially descending trend with off-axis angle from 0° to 45°. A non-monotonic variation of strength with strain rate is further observed: increasing with strain rate up to 500s-1 but decreasing above, which is attributed to failure mode switching from plastic failure to brittle failure. The Tsai-Wu failure criterion, on homogenized cross-ply laminae, is experimentally modified with rate dependence. Further investigation on detailed information of the unidirectional properties should be conducted with the backing-out scheme to establish unidirectional failure criterion.

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Abstract Title	The power law on interface damage evolution of carbon fiber-reinforced polymer laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Huanyu Li[1], Chengyu Guan[1], LihongLiang[1] [1]Beijing University of Chemical Technology Email: lianglh@mail.buct.edu.cn

Abstract

Carbon fiber-reinforced polymer laminates have wide application in chemical and mechanical equipments, inter-laminar interface damage and fracture play an important role in mechanical properties of carbon fiber-reinforced polymer (CFRP) laminates and safety of related components in service. In this study, the damage failure process of CFRP laminates under three-point bending is deeply investigated based on finite element modelling and simulation for a series of thicknesses with different laminate numbers. Damage degree on the interfaces can be obtained with increasing displacement. To analyze the damage evolution behavior of the interface, a catastrophic failure model based on Taylor expansion is established. The damage of the inter-laminar interface was found to follow a power-law characteristic with a power exponent of 0.5. Moreover, the damage rate increases with stacking thickness, and as the displacement approaches the failure point, the damage rate rises rapidly, exhibiting a power-law singularity (-0.5). The results provide a helpful guide for design of laminates.

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Abstract Title	Flexural behaviors and failure mechanisms of CFRP sandwich structures with enhanced dual-phase lattice cores
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yihao Wang[1], Yiru Ren[1] [1]Hunan University Email: yihaowang@hnu.edu.cn

Abstract

Inspired by bionic/metallurgical microstructures, novel dual-phase lattice/ Carbon Fiber Reinforced Polymer (CFRP) composite sandwich structures are proposed to improve the energy absorption (EA). The composite sandwich structures for different dual-phase strengthening strategies are designed, where the topology optimization is used to yield efficient lattice distribution configurations. The experimental samples are fabricated by 3D-printing and three-point bending tests are conducted. The flexural failure process and failure modes are observed and analyzed to reveal the failure mechanisms. Results show that DPL-1-CFRP and DPL-2-CFRP have higher peak load (+24.8% and 18.0%), post-peak average load (42.6% and 20.8%) and specific energy absorption (+7.8% and +21.1%) compared to SPL-1-CFRP. It is indicated that the interactive failure mechanism of dual-phase lattice is effective in improving the mechanical properties of sandwich structure. An interactive failure mechanism is proposed, it represents the occurrence of synergistic deformation between struts rather than a single brittle fracture. Finally, several potential failure mechanisms for the separation of the core and end faces are revealed. The bonding failure modes are highly dependent on the strength of the interfacial binder as well as the fracture toughness of the core, which affects the mechanical properties of the sandwich structure. This novel concept and structural design greatly contribute to improve mechanical properties of sandwich structure.

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Abstract Title	Experimental investigation and numerical modelling of the tapered laminated composite structures under tensile loading
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Chuang Zhang[1], Hongyu Qi[1], Xiaoguang Yang[1*] [1] School of Energy and Power Engineering, Beihang University, Beijing 100191, China Email: zhangchuang629@buaa.edu.cn

Abstract

This study presents an experimental and numerical investigation into the damage mechanisms of tapered laminated composite structures under tensile loading. The tapered laminated composite structures feature a ply drop configuration, resulting in complexities in damage mechanisms, constitutive modeling, and numerical simulation. In this study, samples exhibiting ply-drop characteristics are prepared. In situ X-ray computed tomography (X-CT) tensile tests are conducted to investigate the mechanical behavior and damage evolution. The damage mechanisms, including matrix cracking, delamination, and fiber fracture, are analyzed and quantitatively described. Based on the physical damage mechanisms and experimental data, a constitutive model for damage initiation and progression is developed. This theorical model is integrated into numerical model to simulate the damage behavior under tensile loading. The FEM simulations accurately replicate the observed damage patterns, providing insights into the localized effects of the ply-drop configuration on the structural integrity. Additionally, the influence of various ply-drop parameters on the mechanical performance of tapered laminated composite structures is examined. The results indicate that the ply-drop angle has a significant effect on the initiation and propagation of delamination. These findings offer valuable guidelines for optimizing the design of tapered laminated composites.

Abstract Title	Mechanical performance of bio-inspired helicoidal laminate with high axial properties
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jian Shen, Jia Long Liu Sun Yat-Sen University Email: shenj63@mail2.sysu.edu.cn

Abstract

Bio-inspired helicoidal structure for fiber reinforced composites has drawn increasing attention from researchers globally, because this new type of high-performance composite laminate has the potential to make a significant contribution to the strategic development of lightweight structures. However, most studies only investigated the helicoidal laminates with quasi-isotropic layups where the laminate has to be stacked for several full revolutions. This quasi-isotropic layup has far less applications in the aerospace, automotive, and new energy industry compared to laminates with high axial properties because the laminate components often bear high directional loads. This study investigates the damage pattern of bio-inspired healable helicoidal laminate with high axial properties. The result shows that the helicoidal laminates with high axial properties also possess extradentary out-of-plane strength. The damage mechanism of these helicoidal laminates were also discussed.

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	A multi-physics and multi-scale digital twin framework for highways on the Qinghai-Tibet Plateau
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yingjie Deng[1], J. Woody Ju[2], Shuangjie Wang[1], Jianbing Chen[1], Jin Long[1] [1]National Key Laboratory of Green and Long-Life Road Engineering in Extreme Environment, CCCC First Highway Consultants Co., LTD [2]University of California, Los Angeles Email: dengyingjie.91@163.com

Abstract

In China, transportation infrastructures are being constructed on Qinghai-Tibet Plateau with extreme environmental conditions, characterized by high altitudes, cold climates, frequent freeze-thaw cycles, intense solar radiation and widespread permafrost. Under the highly complex environmental condition, traditional long-term monitoring methods and numerical simulation approaches are inadequate for accurately analyzing and predicting thaw settlement deformation and the evolution of structural performance of permafrost highways. To address this challenge, a multi-physics and multi-scale digital twin framework is put forward and a digital twin platform is developed in this study. The core technologies of physics-data combined driven digital twin framework include intelligent sensing, multi-physics and multi-scale modeling, full spatiotemporal dynamic monitoring, prediction and warning, human-vehicle-highway interaction, and digital twin AI agent. The hygro-thermal-mechanical multi-physics coupling effects and micro-meso-macro multi-scale frozen soil mechanical models are employed to model, analyze, and predict the processes of energy imbalance, thaw settlement, and deformation in permafrost highway subgrades. By establishing and validating digital twins of laboratory test setups and highway field test sections, the modeling accuracy and predictive capability of the digital twin system are verified. The digital twin platform developed based on this framework enables real-time recording, simulation, monitoring, prediction and warning of the operational status of highways throughout their entire life cycle, thereby achieving optimal allocation of informational and material resources for management of highways on Qinghai-Tibet Plateau.

MS10- Gradient damage/phase-field modeling of material’s failure

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Abstract Title	A Multi-Scale Phase Field Framework for Anisotropic Fracture and Strain Gradient Effect of Heterogeneous Materials
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zhiqiang Yang[1], Heliang You[1] [1] Harbin Institute of Technology Email: yangzhiqiang@hit.edu.cn

Abstract

The various fracture characteristics of heterogeneous materials such as anisotropic crack propagation and strain gradient effects are fundamentally linked to their intrinsic microstructural complexity. To analyse the influence of microstructure on macroscopic fracture behavior, this work introduces an innovative multiscale phase field framework based on two-scale asymptotic homogenization.

This proposed model significantly reduces computational costs while maintaining accuracy in capturing the effects of microstructure on crack propagation and ultimate load. Besides, the framework resolves size-dependent fracture phenomena in heterogeneous materials through strain gradient effects. This work advances the predictive modelling of multiscale damage evolution in heterogeneous materials.

Abstract Title	A rigorous irreversible gradient damage model with flexible bandwidth and cohesive law
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	HanWei Huang, Hao Yu, HengAn Wu Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: bbcc@mail.ustc.edu.cn

Abstract

Although the conventional gradient-enhanced damage (GED) model eliminates the mesh dependency inherent in the numerical solutions of local damage models, it exhibits two critical shortcomings. First, it suffers from spurious damage growth, which manifests as non-physical expansion of damage zones with deformation instead of crack localization. Second, the empirical damage evolution formulation leads to inaccurate description of material degradation behavior. To address these issues, this work develops a modified gradient damage model featuring a rigorously constrained irreversible damage bandwidth and a cohesive law-based degradation framework. Theoretical analysis reveals that the damage bandwidth in conventional GED models grows indefinitely with nonlocal variables, leading to unrealistic broadening of damage zones. In the modified model, a degradation function is imposed on the driving term, which enforces a finite upper bound for the nonlocal variable, thereby stabilizing the damage bandwidth. Furthermore, the irreversibility of damage growth is ensured through an optimized stress degradation function, while diverse cohesive laws are systematically incorporated via stiffness degradation function design. Notably, all model parameters exclusively influence the damage morphology without interfering with structural mechanical responses, ensuring physical consistency. Numerical examples across multiple failure modes confirm the capability of the proposed model to prevent spurious damage growth while accurately capturing crack localization and material degradation behaviors, demonstrating significant improvements over conventional approaches.

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Abstract Title	Staggered algorithms for coupled problems: Convergence analysis and application to phase field modeling of thermal cracking
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yonghui Zhao[1], Juhan Jiang[1], Bing Lyu[1], <u>Yongxing Shen</u>[1,2] [1] University of Michigan -- Shanghai Jiao Tong University Joint Institute, Shanghai Jiao Tong University, Shanghai, 200240, China [2] Future Battery Research Center, Global Institute of Future Technology, Shanghai Jiao Tong University, Shanghai, 200240, China Email: yongxing.shen@sjtu.edu.cn

Abstract

The staggered algorithm is one of the most widely used iteration strategies for multi-field coupled problems. This scheme solves for the fields alternately by fixing all but one field and updating the remaining field until all fields converge. It is often stable and robust in solving for the individual fields; however, it sometimes requires many iterations between the fields, leading to high computational costs. This study reveals that a parameter coined the degree of coupling (DOC) is the deciding factor for the convergence behaviors of the staggered scheme.

For two-field coupled problems, the DOC is defined based on the blocks of the Jacobian matrix (or tangent stiffness matrix). It can be proven that the staggered scheme exhibits first-order convergence, with the reduction factor of the residual and the error equal to the DOC. Consequently, when the DOC is close to 0, the staggered scheme quickly converges; when the DOC is less than but close to 1, the convergence is slow; when the DOC is greater than or equal to 1, the staggered scheme is not guaranteed to converge. For instance, in the case of phase-field model for fracture, the DOC increases with loading displacement until it oscillates slightly below 1. Thus, while convergence is guaranteed, it may require many iterations.

For coupled problems involving more fields, the iteration sequence of field variables and the grouping of part fields also significantly influence the convergence behavior. For example, for a three-field coupled problem involving field variables $\mathbf{u}$, $\mathbf{v}$, and $\mathbf{w}$, there exist two cyclic permutations of iterative sequences: $\mathbf{u}-\mathbf{v}-\mathbf{w}$ and $\mathbf{u}-\mathbf{w}-\mathbf{v}$. Additionally, three composite schemes can be formulated by grouping two fields into a mega-field that undergoes internal convergence before updating the third field: $\mathbf{u}-(\mathbf{v}-\mathbf{w})$, $\mathbf{v}-(\mathbf{u}-\mathbf{w})$, and $\mathbf{w}-(\mathbf{u}-\mathbf{v})$. This study defines a DOC for each scheme (e.g., the five schemes above), offering crucial theoretical insights for selecting optimal solution schemes. The predictive capability of this framework is demonstrated through a thermo-mechanical phase-field fracture problem (coupling temperature, displacement, and phase fields).

Keyword: Phase field model; Staggered scheme; Degree of coupling; Convergence behavior; Multi-field coupled; Thermal cracking

Abstract Title	Localized Impact Response of Auxetic Sandwich Panels
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Fanghao Han[1], Balaji Vengatachalam[1], Chenchen Yang[1,2,*], Leong Hien Poh[1,*] [1] National University of Singapore [2] Nanchang University Email: e0866603@u.nus.edu

Abstract

In recent decades, thin-walled protective structures exhibiting auxetic behavior have garnered significant attention due to their promising energy dissipation and impact resistance. However, real-world impacts often occur at *random locations and directions*, yet the influence of these factors on the protective performance of auxetic designs remains *rarely explored*. To address this gap, this paper highlights chiral auxetic structures with in-plane isotropic behavior and an enhanced negative Poisson's ratio (NPR) effect, even under large deformations. Furthermore, the localized impact response of sandwich panels with auxetic and non-auxetic cores is systematically evaluated under generic loading conditions, with varied impact velocity, location, and direction.

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Abstract Title	Multi-scale, multi-physics simulation of pitting corrosion evolution in hydraulic steel structures
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Guofeng Qian[1], Zhen Hu[2], <u>Michael D. Todd</u>[1] [1]University of California San Diego [2] University of Michigan Dearborn Email: mdtodd@ucsd.edu

Abstract

Pitting corrosion is a dominant and costly failure mode for many structural applications, including hydraulic steel structures such as the miter gates that facilitate lock chambers used for inland waterways navigation. Assuming passivation has occurred, we present a multi-physics model that couples the electro-chemical state equations with the local mechanical stress state to predict corrosion pit morphological evolution. A material state phase field model is used to delineate the solid/liquid interface that dictates pit geometry and shape. A probabilistic stress corrosion cracking initiation criterion is proposed that leverages the model-predicted pit morphological properties. Additionally, a surrogate machine learning model with appropriate physical constraint imposed is built of the full multi-physics process to accelerate uncertainty quantification over the pit's growth life cycle. The approach, initially demonstrated on a planar 2D steel specimen, is applied to a full-scale model of a miter gate hydraulic steel structure to generate a limit state risk map.

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Abstract Title	Phase-field method of cohesive fracture
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Ye Feng[1], Lu Hai[2], and Jie Li[3] [1]Northwestern Polytechnical University, Xi'an, 710072, China [2]Leibniz University Hannover, Garbsen, 30823, Germany, [3]Tongji University, Shanghai, 200092, China Email: fengye@nwpu.edu.cn

Abstract

In the variational phase-field or gradient damage model of fracture, the evolution of cracks—including nucleation and propagation—can be succinctly characterized as an energy minimization process. This approach has gained widespread popularity and developed rapidly over the past two decades.

A fundamental problem in this theory is how to reasonably obtain the expression of the total energy functional. In this talk, we will present some recent works in answering the above problem, including a pair of analytic integral transformations revealing the dual relationship between the material's cohesive law and the energy density, and a novel energy decomposition method that can take into account the direction of the crack surface in a variationally consistent way. The above two techniques make it possible to define the mode-I opening and mode II/III shear slip in a phase-field model with diffusive crack description and objectively construct a phase-field model based on the material's mixed-mode cohesive law.

More interestingly, we find that within the proposed model, several widely recognized crack direction criteria—including the minimum potential energy, maximum driving force, and maximum cohesive stress—are consistent and unified. The remaining criteria are simply equivalent stress-space descriptions of the same physical state, derived from the strain-space minimum potential energy criterion through the Legendre transformation.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th – 18th July 2025

Venue: National University of Singapore

Abstract Title	A Multi-Physics Phase-Field Framework for Modeling Chloride-Induced Corrosion and Cracking in Reinforced Concrete under Diverse Marine Environments
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jiang-Rui Qiu[1,2], De-Cheng Feng[1,2] [1] Key Laboratory of Concrete and Prestressed Concrete Structures of Ministry of Education [2] Southeast University Email:jrqiu@seu.edu.cn

Abstract

The accurate prediction of corrosion-induced deterioration is paramount for maintaining the serviceability and durability of reinforced concrete structures. Although substantial efforts have been devoted to investigating chloride-induced corrosion and the associated cracking processes — both theoretically and numerically — using multi-scale and multi-physics approaches, a unified framework that systematically clarifies the underlying mechanisms across diverse marine environments remains absent. This study seeks to bridge this gap by synthesizing previous research to develop a comprehensive, time-dependent framework. The proposed model integrates interactive multi-physics processes, including thermo-hydro-electro-chemo-mechanical couplings, with a dual-phase-field approach to represent the interactive effects of corrosion and fracture. The framework enables precise simulation of the evolution of corrosion morphology and cracking patterns under varying environmental conditions. Comparative analyses and parametric studies are conducted to systematically evaluate the influence of environmental factors and material properties on the degradation mechanisms. By offering a holistic perspective, the proposed framework provides critical insights for the assessment and design of reinforced concrete structures, addressing the complexities inherent in diverse marine regions and advancing the understanding of corrosion-induced damage mechanisms.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	Modelling of corrosion-induced damage process in reinforced concrete
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jing Zeyuan[1], Poh Leong Hien[1] [1]National University of Singapore Email: jing_zeyuan@u.nus.edu

Abstract

Accurate prediction of corrosion-induced damage is essential for timely maintenance and ensuring the durability of reinforced concrete structures. Previous studies have extensively investigated the impact of non-uniform corrosion of reinforcement steel across the cross-sectional plane on concrete damage. However, these studies often neglect corrosion variability along the longitudinal direction of steel reinforcement in 3D analyses. To address this gap, this study employs a 3D localizing gradient damage model. The model analyzes the effects of both cross-sectional and longitudinal non-uniform corrosion products caused by chloride ion penetration on crack formation. Finite element analysis is used to simulate various realistic corrosion patterns, examining their effects on crack initiation, propagation, and damage evolution. Furthermore, the research explores the meso-scale by including randomly distributed aggregates to investigate how aggregate distribution influences crack paths. Results highlight significant differences in concrete cracking behaviour when longitudinal corrosion variability is considered, compared to traditional 2D analyses. Ignoring this variability could substantially underestimate structural deterioration. This improved modelling approach provides valuable insights into accurate assessment methods, aiding better maintenance strategies and extending the service life of reinforced concrete infrastructure.

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	A Semi-Explicit Computational Framework for Efficient Phase-Field Modeling of Complex Fracture Patterns
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Lu Hai[1] [1]The Hong Kong Polytechnic University Email: lu-2025.hai@polyu.edu.hk

Abstract

As a widely recognized numerical approach for capturing intricate fracture patterns, phase-field modeling demonstrates unique advantages in simulating crack evolution processes spanning initiation, propagation, and multi-crack interactions. Despite its theoretical maturity, practical engineering applications face formidable challenges such as convergence difficulties in implicit solvers, stability limitations in explicit time integration schemes, and prohibitive computational resource demands. This study presents a novel semi-explicit computational framework that synergistically combines an explicit temporal operator with the neighbored element technique to address the coupled governing equations of phase-field fracture models. The proposed methodology is rigorously validated through systematic numerical investigations of multiple benchmark problems encompassing diverse fracture modes, demonstrating remarkable consistency with experimental observations and reference solutions in both crack path prediction and load-displacement responses. Comparative analysis reveals a 40-60% reduction in computational expenses compared to conventional explicit approaches while maintaining equivalent accuracy. The developed algorithm successfully resolves the critical trade-off between numerical stability and computational efficiency, particularly showcasing its three-dimensional implementation potential. These advancements paves the way for efficient simulation of complex fracture networks in structural-level components, offering new possibilities for practical implementation in large-scale structural analyses of civil infrastructures and mechanical systems.

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Global-local adaptive meshing method for phase-field fracture modeling
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hao Yu and FengYu Cheng Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: yuhaoo@ustc.edu.cn

Abstract

This presentation develops a global-local adaptive meshing method for the phase-field model of brittle fracture, offering flexible adjustment of mesh density to produce seamless and high-quality adaptive meshes. The method first establishes a direct mapping from phase-field values and displacement errors to a normalized nodal density field, which is used to control the computational accuracy. On this basis, a sampling procedure is performed by detecting the maximum value to progressively place sampling nodes, ensuring that first-level nodes are placed globally while preserving crack location information. Subsequently, a hexagonal seeding algorithm is used to multiply nodes, where the spacing of generated seeds (i.e., higher-level nodes) is adaptively adjusted based on local nodal density requirements to regulate element sizes. A spatial assessment algorithm is utilized to compare the expected nodal spacing of the newly generated node with its distance to existing nodes, which serves as a termination criterion for the loop of the seeding algorithm and effectively prevents the occurrence of low-quality elements. After the seeding process of all nodes is completed, all generated nodes are connected by constrained Delaunay triangulation. This method has been discussed under classical brittle fracture cases with various control parameters (e.g., the mapping function, the expected maximum/minimum element size, and the distance factor) to validate its advantage of reducing degrees of freedom and improving solution efficiency.

Abstract Title	3D Phase-field simulation of crack growth resistance curves in pressure vessel steel considering elasto-plasticity
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Thamaraiselvi Kumaresan[1], Sundararajan Natarajan[1] [1]Indian Institute of Technology Madras Email: me24r001@smail.iitm.ac.in

Abstract

Structural integrity of a Reactor Pressure Vessel (RPV) is a critical factor in determining the operational lifespan of a nuclear power plant. Periodic fracture assessment is essential for RPV as the steel undergoes neutron-induced embrittlement over time, which can compromise structural integrity. The crack growth resistance curve also known as R-curve graphically represents the resistance to crack propagation of the material as a function of crack growth and is an important parameter in fracture mechanics. To ensure safe and extended operation, finite element (FE) based simulations of R-curves play a crucial role in complementing experimental data. These simulations provide a deeper understanding of crack propagation behaviour under varying operational conditions, enabling more accurate predictions of potential failures. A phase-field approach-based finite element framework employing Abaqus user subroutine (UMAT) for elasto-plastic materials is presented. The R-curves are simulated for a notched 3D compact tension specimen subjected to tensile loading. The study investigates the influence of the hardening modulus and length scale parameter on the crack resistance behaviour of the pressure vessel steel made of 20MnMoNi55. Furthermore, the simulated R-curves are compared with the experimentally obtained data at both room and elevated temperatures, demonstrating good agreement between the numerical and experimental results.

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Date: 16th - 18th July 2025
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Abstract Title	Hydraulic fracturing in layered heterogeneous shale: The interaction between adjacent weak interfaces
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	YiLun Zhong, Hao Yu and HengAn Wu Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: zyl990427@mail.ustc.edu.cn

Abstract

Shale is known as the typical layered heterogeneous rock with multiple weak interfaces between different layers, and how to depict the propagation characteristic of fluid-driven fracture in such complex geological structures is critical for hydraulic fracturing engineering. Traditional investigations only focus on the intersecting behaviour of hydraulic fracture (HF) at a single weak interface. Herein, we reveal the propagation of HF in shale formation based on the extended finite element method (XFEM), where multiple weak interfaces and different rock properties are carefully considered in the sandwiched layered structure (SLS). The crack tip singularities at the weak interfaces due to the material discrepancy are characterized by the eigen-function expansion, and the unified enrichment function is constructed to evaluate the stress intensity factors (SIFs) directly without extra computations. The corresponding energy release rate (ERR) criteria are employed to determine the HF propagation direction. By the comprehensive analysis with various dip angle and material/structural properties, the propagation of HF moving across the layered heterogeneous shale are regarded as the interaction between adjacent weak interfaces. For the front weak interface, the inhibition effect could be seen in the fracture penetrating capacity by the rear interface, which reflects contrasting trends due to large material discrepancies of various weak interfaces. The propagation behaviour at the rear weak interface is affected by the facilitation effect from the front interface, and the HF pre-offset at the front interface greatly enhances the facilitation effect on fracture penetrating through shale formations.

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Abstract Title	A Localizing Gradient Damage Model for the Dynamic Fracture of Quasi-brittle Materials and its Simple Implementation in ABAQUS
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Guangyuan Yang[1], Leong Hien Poh[1] [1]National University of Singapore Email: e0751537@u.nus.edu

Abstract

This presentation addresses the dynamic fracture of quasi-brittle materials, such as concrete and ceramics, under various loading rates. With a view towards an ease of implementation, a simple damage model is adopted, together with the necessary constitutive relations, to capture mixed mode fracture behavior reliably. By splitting the energetic contribution into tensile and compressive components, the model only applies damage to the former, thereby preventing spurious compression-induced damage in mixed mode scenarios. Additionally, a history-dependent dynamic increase factor is incorporated to account for rate-dependent effects accurately, without triggering numerical instabilities. Numerical solutions are regularized via the localizing gradient enhancement, yielding sharp damage profiles that resemble macroscopic cracks. To facilitate an ease of implementation in ABAQUS, built-in thermal-mechanical elements are employed in conjunction with VUMAT–VUMATHT subroutines. The predictive capability of the proposed model is verified through simulations of the Tensile Splitting, Compact Tension Test and the Kalthoff–Winkler Test, underscoring its effectiveness in capturing rate-dependent effects in dynamic mixed mode fractures.

MS11- Novel Algorithms, Strategies and Studies for Computational Modeling of Impact Damage

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Date: 16th - 18th July 2025
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Abstract Title	Smoothed Particle Hydrodynamic Analysis of High Velocity Impact on Cryorolled Aluminium Alloy 6082
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Rahul Dubey[1], Akash Kumar[1], Sachin S Gautam[1] [1]Department of Mechanical Engineering, Indian Institute of Technology Guwahati, India Email: rahuldubey665@gmail.com

Abstract

Smoothed Particle Hydrodynamics (SPH), a Lagrangian meshless numerical method, has been effectively utilized to model extreme material deformations at high velocities typical of ballistic impacts. Since there is no mesh to distort, the method can handle large deformations in a pure Lagrangian frame and model dynamic fractures accurately. It is also computationally less expensive than approaches like coupled Eulerian-Lagrangian (CEL) analyses and hence, of current interest. Recent studies have shown ~27% improvement in impact resistance for targets processed through cryogenic temperature rolling (CR) as compared to conventional room temperature rolling (RTR) at certain rolling strains. However, literature lacks rigor in modelling the ballistic impact phenomenon on CR targets using SPH. This study uses commercial finite element package Abaqus/Explicit with SPH to model the high velocity impact on thin CR aluminium alloy 6082 at impact velocities above the target ballistic limit. The residual velocities were validated with experimental data available in the literature to conclude that SPH was capable of modelling the impact phenomenon and target damage to a fair degree of accuracy.

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Date: 16th - 18th July 2025
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Abstract Title	Rapid Prediction and Impact Parameter Identification of Interlaminar Damage via Ensembled Deep Learning Model
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Dazhi Zhao[1§], Yinglong Liu[1§], Yujie Xiang[1], Peng Zhang[1], Keke Tang[1,*] [1]School of Aerospace Engineering and Applied Mechanics, Tongji University, Shanghai 200092, China § Dazhi Zhao and Yinglong Liu contributed equally to the work Presenter Email: zhaodazhi@tongji.edu.cn Corresponding Email: kktang@tongji.edu.cn

Abstract

Interlayer damage in composite laminates, especially from low-velocity impacts, presents a significant challenge in engineering as it compromises structural integrity while remaining hidden. This issue is crucial in safety-critical fields like aerospace, automotive, and civil engineering, where reliable performance is essential. Accurate prediction and identification of impact parameters are vital for improving the design, diagnosis, and maintenance of composite structures.

This study proposes an innovative ensembled deep learning model designed for the rapid prediction of interlaminar damage in composite laminates subjected to low-velocity impacts. The model integrates information from diverse layups and impact parameters, enabling both damage field prediction and parameter identification based on observed damage patterns.

A robust dataset is first generated using the finite element method, simulating various interlaminar damage scenarios that incorporate different layup configurations, impact conditions, and material properties. The damage fields are extracted using a VUMAT subroutine and visualized as contour maps, serving as inputs to the proposed deep learning framework. The framework consists of a generator and a reverse model: the generator, built on a Vector Quantized Variational Autoencoder (VQ-VAE) with a feature fusion module, predicts damage fields based on laminate layup and impact parameters. The feature fusion module integrates information from both undamaged and damaged interlayers for enhanced accuracy. Meanwhile, the reverse model employs a mirror structure to deduce impact parameters from the given damage contour maps.

With its advanced data fusion strategy, multi-layer prediction capability, and inverse reasoning functionality, the ensembled model demonstrates significant applicability in engineering. It accurately predicts interlaminar damage fields across different laminate designs and impacts while identifying impact parameters from observed damage patterns. This deep learning-based tool provides an efficient and reliable approach for damage detection and diagnosis in composite laminates, offering substantial potential for integrating forward and inverse modelling processes in real-world engineering scenarios.

Key words: Interlaminar damage, composite laminates, low-velocity impact, ensembled deep learning, parameter identification

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	A novel mesostructure modelling of concrete with irregular particles based on spherical DOG wavelet and SDF theory
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jingzhe Li [1], Binggen Zhan [1], Peng Gao [1], Huiling Sha [1], Qijun Yu [1] [1]College of Civil Engineering, Hefei University of Technology, Anhui Province, 230009, China; [2] School of Materials Science and Engineering, South China University of Technology, Guangzhou, 510640, China Email: ljz0512@mail.hfut.edu.cn

Abstract

Building the mesostructure of cementitious materials is essential for simulating their fresh state flow behavior and damage progression under load after hardening, several advanced methods, such as Anm, DOG-based, and VOX methods, have been developed to construct the mesostructure of cementitious materials with irregularly shaped particles, including cement paste, mortar, and concrete. However, the accurate representation of irregularly-shaped particles and efficiently packing of mesostructures with high volume fractions of existing methods are unsatisfactory. An adaptive meshing method, called DOG-based WSCVT method, is proposed in this paper to convert the wavelet-based mathematical representation of particle surface into a uniformly distributed triangular mesh, which can preserve particle shape characteristics using fewer surface points. A novel particle packing algorithm is proposed and validated based on signed distance field (SDF) approach. Results shown that 1500 ~ 2000 surface points iterated by DOG-based WSCVT method are sufficient to represent the original particle shape with a shape parameter error below 1%. The proposed packing algorithm is respectively improved by ~50 times and ~10000 times compared to the VOX and Anm/DOG-based methods.

Key words: Irregularly-shaped particle; Spherical DOG wavelet; Adaptive meshing; Signed distance field; Packing algorithm; Mesostructure.

Abstract Title	3-D Fatigue Crack Growth Simulations Using Continuum Damage Mechanics and XFEM
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	V.B. Pandey[1,2], I.V. Singh[2], B.K. Mishra[2] [1]Department of Mechanical Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj, Uttar Pradesh, India [2] Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India Email: vbpandey@mnnit.ac.in

Abstract

In this work, the extended finite element method (XFEM) is combined with continuum damage mechanics (CDM) for performing the 3-D fatigue crack growth simulations. In this framework, a discrete crack is represented through enrichment functions in the finite element domain. The CDM-XFEM combination helps us to simulate the crack propagation at relatively coarser meshes. Mesh regularization techniques are utilised to avoid the mesh dependency. The fatigue life of a cracked specimen is estimated through fatigue damage model. The 3-D model of compact tension specimen is simulated and obtained results are compared with the published experimental results. These results confirm that the combination of CDM-XFEM is an easy and efficient method to perform the 3-D fatigue crack growth simulations.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Thermomechanical fracture in functionally graded materials using an adaptive phase-field approach
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Anna Mariya Shajan [1], Raghu Piska [2] and Sundararajan Natarajan[3] [1,2] Department of Civil Engineering, Birla Institute of Technology and Science Pilani Hyderabad Campus, Hyderabad, India [3] Department of Mechanical Engineering, Indian Institute of Technology Madras, India Email: raghupiska@hyderabad.bits-pilani.ac.in

Abstract

Functionally graded materials (FGM) are advanced composites engineered with a continuous variation in composition, microstructure, and properties, ensuring a seamless transition between constituent materials. Understanding and predicting their fracture behavior is crucial for optimizing structural performance. Due to the inherent material gradation, fracture behavior in FGMs is highly complex, necessitating robust computational models. The phase-field fracture model (PFM) has emerged as a powerful tool for simulating crack initiation and propagation, as it naturally captures crack morphology, branching, and arbitrary growth. However, the PFM suffers from high computational cost due to the need for fine spatial discretization to resolve the length scale parameter. To address this, we propose an adaptive mesh refinement strategy that employs the phase-field variable threshold as an error indicator, enabling localized refinement near crack regions. A quadtree decomposition method is employed for spatial discretization, where hanging nodes are effectively managed by representing elements as arbitrary polygons. The material gradient in FGM is modeled using a power-law function, ensuring an accurate representation of spatially varying properties. The governing coupled equations are efficiently solved using a staggered scheme, enhancing numerical stability and convergence. Our results demonstrate that the adaptive phase-field framework significantly improves computational efficiency while maintaining high accuracy. The numerical simulations provide valuable insights into fracture path evolution, load-displacement behavior, crack tip velocity, and energy dissipation across various material gradations and loading conditions. The findings emphasize the crucial role of material gradation and thermal and mechanical effects in fracture behavior, offering a deeper understanding of crack evolution in FGM. This work highlights the effectiveness of the adaptive phase-field approach in analyzing fracture mechanics in FGM, offering a computationally efficient tool for designing FGM structures with enhanced resilience under complex loading environments.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Enhancing Concrete Damage-Plasticity Model II (CDPM2) Under Complex Loading Conditions
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yuening ZUO[1], Leong Hien POH[1] [1]National University of Singapore Email: e0215340@u.nus.edu

Abstract

The Concrete Damage-Plasticity Model II (CDPM2) is a built-in constitutive model for cementitious materials in LS-DYNA, and its capability to predict the behavior of normal-strength concrete (NSC) under quasi-static loading has been demonstrated in the literature. However, under complex loading conditions—particularly when specimens are subjected to high levels of both hydrostatic and deviatoric stress—noticeable discrepancies emerge between the model predictions and experimental observations. This research aims to enhance the applicability of CDPM2 to NSC in such complex stress states by refining its yield surface formulation and the associated hardening and softening evolution laws. The proposed modifications are validated through comparison with experimental results, demonstrating improved agreement in key mechanical responses.

MS12- Application of Damage Mechanics in Civil Engineering Structures

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Estimation of Low-Cycle Fatigue Strength Based on Low-Cost Tests
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Dragoslav M Sumarac[1], Zoran B. Perovic[2], Demir Vatic[1], Timur Curic[1], Izet Cama[1], Maosen Cao[3] [1] Department of Technical Sciences, State University of Novi Pazar [2] Faculty of Civil Engineering, University of Belgrade, Serbia [3] College of Mechanics and Engineering Science, Hohai University, Nanjing, China Email:dragosumi@gmail.com

Abstract

In Civil Engineering, low-cycle fatigue often occurs in structures subjected to cyclic loading, such as seismic loading in high-rise buildings or severe loading conditions on bridges. In Mechanical Engineering, machine parts are frequently exposed to low-cycle fatigue. In a previous paper (International Journal of Damage Mechanics, https://doi.org/10.1177/10567895241282416), the authors demonstrated that a fatigue damage approach based on an elastoplastic damage model at the micro level is capable of predicting the number of cycles before rupture. This approach uses a unit element constructed with a hysteretic operator, which employs an analytical solution and corresponding numerical implementations for calculating heat dissipation. These micro-elements, each characterized by distinct fracture energy limits, are connected in parallel to create a material model at the macro level. The model utilizes the Preisach hysteretic operator, which has been well-established in solving problems involving various hysteretic phenomena.

In the present paper, we aim to explore the correlation between the fatigue strength of low-cycle fatigue and the strength measured by the Charpy V-notch (CVN) test. While this relationship might initially seem unlikely, we hypothesize that an energy-based approach could reveal a correlation under certain loading conditions. The Charpy CVN test is based on the energy required to fracture materials under impact loading. Additionally, our previous model for low-cycle fatigue strength, using the Preisach model, is capable of calculating the energy required for the rupture of elements. Our focus will be on materials that can withstand large plastic deformations, such as aluminum, copper, and, particularly, mild steel used in civil engineering applications.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th-18th July 2025

Venue: National University of Singapore

Abstract Title	Quantification of probabilistic damage under dynamic excitation in gear digital twin system
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yawen Zhang[1], Zhendan Lu[1], Yunxia Chen[1] [1]BeihangUniversity Email: ZhangYawen@buaa.edu.cn

Abstract

Gears are essential components in numerous industrial mechanical applications, where they often operate under complex dynamic excitation conditions. With the rapid development of digital twin technology, the precise quantification of probabilistic damage under dynamic excitation has become a critical challenge in the health monitor and maintenance of mechanical systems. This study focuses on developing a probabilistic damage quantification method that considers material response uncertainties under dynamic excitation scenarios within the framework of a gear digital twin system. By integrating dynamic models, real-time operational data, and probabilistic damage quantification modelling, a virtual-physical mapping of gear damage evolution is established. The study investigates probabilistic damage quantification methods induced by material response uncertainties under complex dynamic excitation conditions and proposes a probabilistic damage quantification approach for interface fatigue based on the Zaretsky fatigue criterion. This enables the estimation of the probability distribution of damage states under multiple dynamic operating conditions, providing robust assessments under uncertain material responses and environmental conditions. Simulation and experimental data sets validation demonstrate the effectiveness of this method in quantifying damage and predicting degradation trends across various dynamic scenarios. This approach offers a significant tool for improving the predictive maintenance of gear systems, enhancing operational reliability, and supporting intelligent decision-making in industrial systems.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Parameters sensitivity analysis of mechanical property of soil-rock mixtures based on mesoscopic numerical calculations
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Mei Tao[1], Hao Zhang[1], <u>Li Cui</u>[1], <u>Linfei Zhang</u>[2], <u>Shuigen Hu</u>[1] [1]Chuzhou University [2]Zhejiang A&F University Email: tmei@chzu.edu.cn

Abstract

Abstract: Because the differences of the mechanical properties of the meso-components of soil-rock mixtures (SRM), when subjected to external loads, the rock blocks usually do not easily undergo deformation and failure, and crack propagation generally occurs in the soil. This is the main reason for the deformation and failure of SRM. Therefore, it is necessary to conduct a sensitivity analysis of the mechanical properties of SRM with respect to the soil parameters. To study the influence of soil parameters, such as elastic modulus, internal friction angle, and cohesion, on the mechanical properties of SRM, this paper employs the orthogonal experimental method to analyze the sensitivity of soil parameters for the mechanical properties of SRM through mesoscopic numerical calculations, aiming to determine the extent of the influence of these parameters on the mechanical properties of SRM. The research results demonstrate that the internal friction angle of the soil has the greatest influence on the strength of soil-rock mixtures, followed by the elastic modulus, while the Poisson's ratio has the least impact.

Keywords: soil-rock mixtures; sensitivity analysis; orthogonal experimental method; mechanical properties; mesoscopic numerical calculations

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Calibration of the K&C Model for Singapore-Sourced Normal-Strength Concrete under Quasi-Static Loading
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jie Zhang[1], Leong Hien Poh[1] [1]National University of Singapore Email: Jie-cee@nus.edu.sg

Abstract

This study presents a modification and calibration of the Karagozian & Case (K&C) concrete model to accurately characterize the mechanical behavior of normal-strength concrete commonly used in construction projects in Singapore. The investigated material exhibits a strength grade ranging from C35/45 to C50/60. A comprehensive set of quasi-static experiments was conducted, including uniaxial compression, gauged reactive confinement tests, and four-point bending tests. In addition, experimental data from triaxial loading tests were collected and referenced. These results were used to calibrate key K&C model parameters under quasi-static conditions, including strength surface parameters, softening behavior, the yield surface evolution (η–λ relationship), and the equation of state (EOS). The calibrated model demonstrates improved accuracy in simulating the nonlinear response of concrete under complex stress states.

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	The Multi-fractal Scaling Laws (MFSL) of tensile strength and fatigue limit: Experimental confirmation for initially uncracked specimens and scale-ranges beyond one order of magnitude
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Alberto Carpinteri[1], Federico Accornero[1] [1]Shantou University, Shantou, China Email: federico@stu.edu.cn

Abstract

Multi-fractal Scaling Laws (MFSL) best-fit the experimental data of tensile strength and fracture energy of concrete-like materials, as well as the data of fatigue limit and fatigue threshold of metal alloys, when initially uncracked specimens and size-scale ranges beyond one order of magnitude are considered. If the concept of self-affinity (in addition to that of self-similarity) is applied, the absolute value of slope in the bi-logarithmic scaling laws is the highest and equal to 1/2 (or 1/4 in the case of fatigue threshold) at the smallest scales, whereas it tends to vanish at the largest, the diagram presenting a horizontal asymptote and a constant limit value that can be considered as a material property. Concerning concrete-like materials, this homogenization effect for tensile strength is captured by the MFSL very satisfactorily in the case of initially uncracked structural elements. The MFSL has been adopted by the European Standards for concrete and reinforced concrete structures. It also works well for ceramic materials at the micro- and nano-scales (scale shifting with respect to concrete). On the other hand, the Size Effect Law (SEL) works well only for initially cracked specimens, when the initial crack length is proportional to the structural size-scale, and its concavity results to be downwards. On the contrary, the experimental relative crack depth at the peak load is large in small specimens and small in large specimens, when the specimens are initially uncracked. In addition, the concavity of the experimental data in this case results to be always upwards, like that of MFSL. Concerning metals, in order to investigate the specimen-size effect on fatigue limit, an experimental campaign was carried out on five groups of hourglass specimens made of EN-AW6082-T6 aluminum alloy, with different diameters of 3, 6, 12, 24, and 30 mm (just a scale-range of one order of magnitude). The specimens were tested by an ultrasonic fatigue testing machine (loading frequency: 20 kHz) up to failure or run-out at 10^10 cycles. Fractal and multi-fractal best-fitting is performed to assess the specimen-size effect in very-high cycle fatigue (VHCF). The experimental results confirm the MFSL for fatigue limit, its evident upwards concavity emphasizing the inadequacy of both fractal (straight line) and SEL (downwards concavity) in correctly describing the trends of extreme experimental data related to initially uncracked specimens.

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Venue: National University of Singapore

Abstract Title	Cumulative damage model for uniaxial and multiaxial fatigue failure
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zoran B. Perovic[1], Dragoslav M Sumarac[2], Stanko B Coric[1] , Maosen Cao[3], Izet Cama[2] [1]Faculty of Civil Engineering, University of Belgrade, Serbia [2] Department of Technical Sciences, State University of Novi Pazar [3] College of Mechanics and Engineering Science, Hohai University, Nanjing, China Email:dragosumi@gmail.com

Abstract

The service life of engineering components and structures can be significantly reduced when subjected to fatigue loading. While loading conditions are well-defined during the design phase, during operation, random loading and fatigue damage can alter the expected multiaxial stress state in the material. This study develops models for analyzing fatigue damage under both uniaxial and multiaxial stress states. For uniaxial fatigue, the focus is on low-cycle fatigue and an energy-based approach, where plastic energy serves as the primary governing parameter. A cell-based model is employed to compute stress and hysteretic energy loss efficiently, using various distribution functions to determine cumulative damage. Specifically, as cells are progressively removed from the global model, the damage measure is represented by a point on the cumulative distribution function, defined by its associated probability density.

For the more complex challenge of multiaxial fatigue, similar tools are applied. In this case, fatigue damage is defined up to crack initiation (i.e., the ultimate failure limit, $D \ll 1$) rather than the theoretical total degradation limit. The critical plane approach is a highly effective method for multiaxial fatigue analysis, although equivalent strain and stress methods also incorporate critical plane considerations. Consequently, the evolution of parameters on specific planes forms the core of the multiaxial fatigue damage model presented here. Evaluating multiaxial fatigue damage becomes particularly complex under variable and nonproportional loading conditions. The goal is to simplify the multiaxial strain or stress state into an equivalent damage condition. The accumulated damage calculations from the uniaxial energy-based approach can be extended to random loading in a multiaxial stress state. Data from tubular specimens and parameters from multiple models are used to correlate fatigue damage with life estimation. The contribution of different cumulative damage measures in the critical and other material planes is also examined.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Beam based damage model for the fracture of architected lattice materials
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Himanshu[1], Biswajit Pal [2], <u>Ananth Ramaswamy</u>[1] [1]Indian Institute of Science, Bangalore, India. [2]Central Building Research Institute, Roorkee, India. Email: ananth@iisc.ac.in

Abstract

A critical review of the literature reveals that studies that focus on the fracturing aspects of structural elements of Architected lattice materials (ALM) are limited, especially those that employ beam kinematics coupled with phase-field (PF) damage models with the aim to reduce the computational efforts with an equivalent 2D model. Consequently, in this study, a beam-based PF model employing Timoshenko theory is developed to analyze a thick beam's damage behavior in an ALM. The model introduces a homogenized damage function to account for the overall damage state across the cross-section, rather than explicitly solving damage variations within the cross-section. With respect to the 2D descriptions of damage over the cross-section, two different damage approximation functions are considered: constant and parabolic. The present study assume that the evolution of damage is governed by the tensile axial energy, shear energy, and a fraction of flexure energy. Simulation results shows that the fraction of flexural strain energy(α) that is responsible for the evolution of damage, varies with the depth-to-length ratio of the beam. Validation of the model-predicted load-displacement response and damage behavior comparing 3D with 2D simulation and experimental results highlights the predictive capacity of the proposed model, along with a huge reduction in the computational effort.

Abstract Title	Generative AI Techniques for Vibration-based Structural Health Monitoring
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jun Li 1,* 1 Centre for Infrastructural Monitoring and Protection, School of Civil and Mechanical Engineering, Curtin University, Bentley, Western Australia 6102, Australia. Email: junli@curtin.edu.au

Abstract

This paper proposes the development and application of generative AI techniques for vibration-based structural health monitoring of civil engineering structures. The first application addresses the challenges related to data imbalance and inadequacy by proposing the development and application of diffusion models for structural health monitoring data augmentation and generation. The reliability and accuracy of data generation are validated through two experimental cases studies on modal identification and lost data reconstruction. The second application focuses on generating realistic and synthetic 3D datasets which can be for vibration displacement response measurement. The development and application of generative AI techniques will be discussed in this talk.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Application of Bispectrum Analysis to Inspection of Fatigue Damage of Beam Structures under the Noise Environment
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Li Cui[1], Mei Tao[2], Hao Zhang[2], Shuigen Hu[2], Shuai Li[1] [1]Hohai University [2] Chuzhou University Email: cuili1996@chzu.edu.cn

Abstract

In practical engineering, many structures are located in complex environments, which are reflected in various aspects such as the environment they are in and the loads they are subjected to. When analyzing structural monitoring data, in addition to the loss of structural damage characteristic information caused by algorithm and structural nonlinearity, signal noise caused by multiple factors is also one of the main reasons for drowning out signal characteristics. This article mainly explores the ability of the bispectrum analysis method to avoid the influence of noise in the damage detection of simple beam structures. Taking the cantilever beam structure as the research object, from the perspectives of numerical simulation and physical experiments, bispectrum analysis is adopted to study the nonlinear dynamic characteristics of beam structures containing breathing cracks. Research has shown that bispectrum analysis can effectively identify nonlinear damage in cantilever beam structures and has good resistance to noise. Compared with the commonly used signal analysis methods in engineering, bispectrum analysis can not only better preserve the structural nonlinear characteristics in monitoring signals, but also overcome the complex environment in engineering practice, providing new ideas for exploring data processing in engineering structural monitoring.

Abstract Title	Structural Damage Detection by Progressive Continuous Wavelet Transform and Singular Value Decomposition of Noisy Mode Shapes
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Shuigen.Hu[1] , Zhichun. Ding[2] [1] College of Civil and Architecture Engineering, Chuzhou University, Chuzhou, 239000, China [2]Department of Engineering Mechanics, Hohai University, Nanjing 210098, People's Republic of China Email: hushuigen@chzu.edu.cn

Abstract

Damage identification from structural mode shapes has become a research focus for years. Mode shapes can provide spatial information about a structure but are not sensitive to its local damages. In contrast, modal curvature is highly sensitive to the local damage and can provide accurate information about the location of such damage. However, an intrinsic deficiency of modal curvature is its susceptibility to the measurement noise present in the mode shape from which the modal curvature is generated. This noise can obscure the damage features. To address the deficiencies, this study provides a new method of identifying damage using synergetic actions of the continuous wavelet transform and the singular value decomposition to process mode shapes. With this method, the continuous wavelet transform is first implemented on the mode shape, giving continuous wavelet coefficients of mode shape, then the singular value decomposition is performed on the continuous wavelet coefficients to produce a new damage feature, the singular image of continuous wavelet coefficients (SICWC) of the mode shape. This new damage feature has the distinct capabilities of suppressing noise, canceling global trends in a measured mode shape involving noise, and thus intensifying the singular feature caused by damage. These capabilities improve the sensitivity to damage and accuracy of damage localization. The SICWC of mode shapes is demonstrated by several numerical examples involving a cantilever beam, with emphasis on characterizing damage in noisy environments. It is further validated experimentally on a cracked aluminum beam with mode shapes acquired by a scanning laser vibrometer. The SICWC of the mode shape essentially overcomes the deficiency of conventional damage detection techniques using mode shapes and circumvents the drawback of modal curvature measurements, providing a new dynamic feature well suited for damage identification in noisy environments.

MS13- Modeling and Simulation of Damage in Elastic and Plastic Materials

Abstract Title	Numerical Analysis for Evaluating the Structural Design of a Lunar Inflatable Habitat Module
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Keisuke Mukaida[1], Li Yutong[2], Naohiro Uyama[3], Jun Kojima[3], Jun Koyanagi[2] [1]Graduated school of Tokyo University of Science [2]Tokyo University of Science [3] Shimizu Corporation Email: 8224569@ed.tus.ac.jp

Abstract

Japan's Ministry of Land, Infrastructure, Transport and Tourism is leading a project to develop lunar facilities by 2030. Among its themes, "Ground Verification Model for Lunar Inflatable Habitat Module" proposes using membrane structures to address weight and volume constraints of rocket transport. Membrane structures are lightweight, reduce transportation resources, and can form large spaces from minimal materials.
Figure 1 illustrates the concept of the habitat module. The habitat module features a 5-meter diameter spherical design, connected by 2.4-meter metal lids to expand the living space. Membranes must withstand 14.9 kN per 3 cm width with a safety factor of 4. Seam strength, weaker than the membrane itself, is improved with stress-reducing ropes.
This study focuses on the creation of a ground verification model and the execution of burst tests. By using numerical analysis with ABAQUS, it aims to explore the relationship between strength and structure to address design challenges, ultimately achieving a balance between the advantages of membranes and the required strength. In particular, the research emphasizes evaluating the strength of welded seams essential for membrane construction and designing metal components for burst tests.

Numerical Analysis of Joint Length and Strength in Membrane Material Seams
During membrane material fabrication, individual segments are joined using heat welding, resulting in seams that are weaker than the base material. To enhance seam strength, increasing the joint length is necessary; however, excessive joint length undermines the benefits of inflatable membranes. Additionally, seam failure often occurs due to localized stress, limiting the effectiveness of lengthening the joint. Therefore, the aim is to clarify the relationship between joint length and seam strength, providing essential insights for designing seams with optimal performance, even if determining a singular "optimal" joint length is challenging within this study.

Tensile strength tests for membrane seams are conducted using single-lap shear tests. To simulate this in numerical analysis, the test setup was reproduced, and both damage analysis and elasto-plastic analysis were employed. The simulation incorporated interfacial failure between fibers and resin, which predominantly occurred during experiments, as well as cohesive failure of the resin itself. For interfacial failure, cohesive elements were employed, and failure was determined using a quadratic nominal stress criterion based on stresses purely normal to the interface or purely in the first and second shear directions. Additionally, for cohesive failure of the resin, an elasto-plastic analysis was performed, introducing a failure criterion based on equivalent plastic strain that accounted for stress triaxiality. This method was used to investigate the relationship between joint length and seam strength.

Design of Module Connection Covers

To conduct burst tests cost-effectively, alternative covers are being considered to replace the large, single-piece metallic discs typically used for module connections. These test covers must withstand the 1-atmosphere internal pressure applied to the membrane material without failing before the membrane. To ensure this, the structural and strength relationships of the covers are being analysed using finite element method (FEM). The analysis incorporates damage analysis and elasto-plastic analysis, utilizing stress-strain relationships based on isotropic hardening rules. For metal failure, a failure criterion based on equivalent plastic strain was introduced, which accounts for stress triaxiality to evaluate the strength of the metal components.

Specifically, the design aims to reinforce a 2.2 m diameter iron plate to withstand 1 atmosphere of pressure. Proposed measures include welding grid-shaped ribs onto the plate and adding washers near bolt areas for additional support. These reinforcements are intended to achieve a manufacturable structure capable of enduring the required loads.

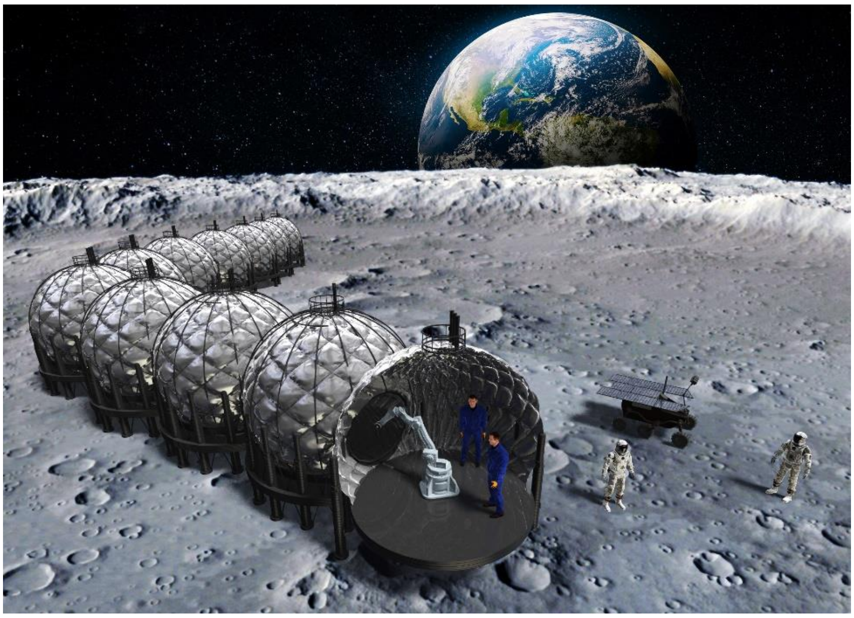

Fig. 1 illustrates the concept of the habitat module

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Damage evolution in Brazilian splitting tests with different loading angles: experimental and numerical analysis
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jiaxin Feng[1], Xu Yang[1], Gao Li[1] [1]Southwest Petroleum University Email: feng462899@126.com

Abstract

The Brazilian splitting test measures the tensile strength of rocks but is criticized for assuming central crack initiation, which often contradicts experimental results. Previous scholars proposed the flattened Brazilian splitting test, with prefabricated loading platforms with a certain angle (2α). Studies show that a central crack initiates when 2α > 20°, and correction factors have been introduced. However, rock heterogeneity challenges these isotropy-based corrections. This study investigates the damage and failure characteristics of sandstone specimens with different loading angles in the Brazilian splitting test, offering new insights for accurately determining tensile strength using the flattened Brazilian splitting test.
Five triaxial and three uniaxial compression tests were conducted to determine the YC formation's rock mechanics parameters. Using DIC technology, four sets of Brazilian splitting tests with different loading angles were performed. Based on XRD analysis, a discrete element numerical model reflecting the YC formation's geology was constructed, and simulations were conducted. A method to characterize microcracks to macroscopic cracks was proposed, investigating the spatiotemporal evolution of damage and failure. The results of direct tensile and Brazilian splitting tests were compared. Spatiotemporal evolution analysis reveals that numerous microcracks form before macroscopic failure. The macroscopic crack characterization method captured phenomena not observed in experiments. For disc specimens, initial end failures create a platform, but the smaller platform is insufficient to support central failure, causing cracks to propagate from the ends to the center. For flattened specimens, cracks initiate at the center, exhibiting significant heterogeneity. The first peak stress occurs when the central crack propagates. As the crack extends towards the ends, stress decreases, but the flattened surface prevents easy propagation, causing stress to rise again. Finally, shear and tensile failure at the ends lead to a final stress drop.

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Abstract Title	Simulation of the influence of initial voids on the mechanical behaviour of steel-concrete-steel structures
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Ludovic Jason[1], Martin Debuisne[2], Luc Davenne[2] [1] Université Paris-Saclay, CEA, Service d'Etudes Mécaniques et Thermiques, 91191, Gif-sur-Yvette, France [2] Laboratoire Energétique Mécanique Electromagnétisme (LEME), UPL, Univ Paris Nanterre, F92410 Ville d'Avray, France Email: ludovic.jason@cea.fr

Abstract

Steel-concrete-structures, which are composed of a concrete core related to outer steel plates through steel dowels, are of increasing interest due to their modularity, performance and durability. However, the presence of two outer steel plates makes difficult any visual monitoring of the quality of concrete pouring and the detection of potential defects. It thus requires specific methodologies, based either on experimental approaches for detection (nondestructive methods) or on numerical strategies to evaluate the potential consequences of concrete defects on the mechanical behavior. In this contribution, the structural consequences of a concrete defect are investigated through its impact on the dowel-concrete interaction at a local scale. Classical push-out tests are first simulated, using a refined approach, specifically developed for this scope [1] and based on damage mechanics for concrete. It includes "energetic" regularization in both tension and compression for concrete and the introduction of joint elements at the junction between the dowel and the steel plate. Validation is obtained by comparison to experimental results.
Voids are then introduced into the mesh to represent defects in concrete. The impact in terms of stiffness and resistance is especially studied. A generic sensitivity analysis is proposed to identify key parameters, using surface methodology. The most critical defect type and its severity is particularly discussed.

[1] Martin Debuisne, Luc Davenne, Ludovic Jason. On the need of compressive regularization in damage models for concrete: demonstration on a modified Mazars model. Applied Mechanics, 2024, 5 (3), pp.490-512.

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Abstract Title	Interfacial Dislocation Networks in Nickel-based Superalloys via Atomistic Simulations
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Haifei Zhan[1], Bin Dong[1], Chaofeng Lü[2,1] [1]Zhejiang University, China [2] Ningbo University, China Email: zhan.haifei@zju.edu.cn

Abstract

Ni-based single crystal superalloys are indispensable in aerospace industry, enduring extreme temperatures exceeding 1,100 °C. Their outstanding mechanical characteristics stem from a unique two-phase microstructure comprising $L1_2$ ordered Ni_3Al precipitates (γ' phase) embedded in a ductile disordered face-centered cubic Ni matrix (γ phase). The interface between these two phases hosts interfacial dislocation networks (IDNs), crucial for enhancing their mechanical performance. Despite extensive works on IDNs, existing studies, particularly atomistic simulations, have largely overlooked the dynamic changes of lattice parameters occurring during service, such as alloying elemental diffusion, temperature variation, and extreme centrifugal forces. Such variation of lattice parameters for a given γ' phase size is anticipated to profoundly influence the IDNs, a crucial aspect that has been rarely discussed. In the current work, we unveil the size-dependent patterns of IDNs for the first time. We reveal that these patterns are governed by moiré patterns at the interface, dictated by the lattice misfit. Particularly, the compatibility between the moiré superlattice parameter and the γ' phase size profoundly impacts the integrity of the dislocation networks. Additionally, we demonstrate how these initial IDNs contribute to pseudo-elastic behaviour and influence subsequent dislocation activities during plastic deformation.

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Modelling of damage and fracture for aluminum alloy tailor welded blanks considering material heterogeneity
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Pengfei Gao[1], Mengyan Fei[1], Zhipeng Ren[1], Mei Zhan[1] [1] Northwestern Polytechnical University Email: gaopengfei@nwpu.edu.cn

Abstract

Plastic forming of tailor welded blanks (TWB) is an effective way to realize the lightweight, low cost and short cycle manufacturing of aerospace and automotive components. However, in this kind of plastic forming, the heterogeneous microstructure in weld significantly increases the forming complexity and stimulate the complex damage and fracture. These strongly affect the forming limit of components fabricated from TWB. In this study, the damage and fracture behaviors were explored based on the in-situ SEM tensile test in the deformation of aluminum alloy TWB. And the effects of microstructure on the damage and fracture were analysed. Moreover, the corresponding effect mechanism was revealed based on the micromechanical simulation. On these bases, a coupled deformation and damage constitutive model considering the microstructure effect was established. During the modeling, the damage was characterized in terms of the evolutions of coexisting multi-type voids. The multiple-type voids were modeled separately as functions of the local micro-strain/stress of their respective phases and microstructure characteristics according to the micromechanical mechanisms. Furthermore, a self-consistent method was employed to calculate the heterogeneous micro-strain/ stress of phases and the overall macroscale flow behavior of the multiphase aggregate. In particular, the constitutive behavior of each phase in the self-consistent method was modeled by coupling the softening effect of void evolution and microstructure characteristics. Applied to the 2219 aluminum alloy, the developed model accurately predicts the flow stress, damage evolution and fracture behavior under various microstructures and those of tailor-welded blanks with a gradient microstructure.

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	A Local Damage Model Using the Heish-Ting-Chen Equivalent Strain for Quasibrittle Materials
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hemam Amarjit Singh[1] and Rimen Jamatia[2] [1,2] Indian Institute of Technology Jammu, Jammu and Kashmir, India, 181221. Email: hemam.singh@iitjammu.ac.in

Abstract

Fracture in quasibrittle materials is complex due to their irregular crack patterns and damage evolution. This study develops a local damage model, implemented using UMAT, an ABAQUS user-subroutine platform, to simulate crack initiation and propagation. An equivalent strain measure, derived from the Heish-Ting-Chen failure criterion, is introduced to govern damage evolution. To ensure mesh-independent results, the model incorporates both fracture energy and characteristic length. Numerical validation is carried out using experimental studies, including the three-point bending test by Hoover et al. (2013), the L-shaped test by Winkler (2001), and the mixed-mode fracture test by Nooru-Mohamed (1992). The results show that the proposed approach effectively captures damage progression and crack growth, while the predicted load-displacement response aligns well with experimental data. This demonstrates the model's reliability in simulating fracture behavior in quasibrittle materials.

Abstract Title	90-degree peeling of elastic thin films from elastic soft substrates: Theoretical solutions based on cohesive zone models and experimental verification
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hao Long[1], Yanwei Liu[1], Hanbin Yin[2], Yan Zhang[3], Qingning Yang[1], Yueguang Wei[1] [1]Peking University [2]Tsinghua University [3]Institute of Mechanics, Chinese Academy of Sciences Email: mtlonghao@pku.edu.cn

Abstract

Peeling of thin films, a typical example of interfacial fracture, has been widely used in adhesion measurement, film transfer and bio-inspired design. Most previous studies focused on the peeling of thin films from rigid substrates, but soft substrates are common in practical applications. Herein, we use cohesive zone models to characterize the interface, and obtain the theoretical solutions of the 90-degree peeling of elastic thin films from elastic soft substrates. The theoretical solutions match well with the results of finite element method, including the load-displacement curve and the substrate deformation during peeling. With the present solutions, we can simultaneously extract the interfacial strength and the interfacial fracture energy from the results of peeling experiments. Furthermore, we obtain the power scaling law of the maximum peeling force, where the scaling exponent depends on the substrate elasticity and the shape of cohesive zone models. These results can help us measure the interfacial properties of stiff film/soft substrate systems via peel tests, and regulate their peeling behaviors by interface design.

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Abstract Title	Strain gradient induced transition of facture mode in micro-porous metallic materials
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yanwei Liu[1], Hao Long[2], Hang Li[2], Yueguang Wei[2] [1]Beihang University [2] Peking University Email: 13716459790@163.com

Abstract

The fracture behavior of micro-porous metallic materials is closely related to the characteristics of their internal microvoids, including void size, spatial distribution, shape, porosity, etc. This study primarily investigates the influence of strain gradient hardening effects induced by micro-void size on the fracture behavior of micro-porous metallic materials. Firstly, we established a low-order strain gradient plastic fracture model and derived its general formulations in both Cartesian and curvilinear coordinate systems. Secondly, the void growth problem of cylindrical and spherical voids in an infinite body was solved to explore the coupled effects of strain gradient hardening and damage softening on void evolution. Subsequently, a finite element numerical solution algorithm was developed by integrating the radial return method and staggered solution scheme. Finally, the tensile behaviors of porous metals with identical void characteristics at different scales were computed, revealing the role of strain gradient effects in the transition of fracture modes in micro-porous metallic materials. Our research provides insights into understanding the strength-toughness behavior of micro-porous metallic materials.

Abstract Title	Numerical Investigation on Precipitation Hardening of Mg-Gd Alloy
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yang Chen[1], Chunyan Yang[1] [1] Guilin University of Electronic Technology Email: chenyang@guet.edu.cn

Abstract

The second phase particles in magnesium alloys could affect mechanical properties of the material significantly. In this work, 3D finite element models with explicit incorporation of second phase particles are established. The simulations are calibrated with the experimental results of the alloy Mg-1Gd. The influences of factors, such as particle distribution, size and orientation of cylindrical particles, on precipitation hardening are investigated in detail. Three interface conditions between particles and the matrix – perfect bonding, high and low strength bonding – are studied at the same time. The interface conditions are shown to exert stronger influence on precipitation hardening compared to the factors of particle distribution and size. In contrast, the influence of the orientation of cylindrical particles at grain boundaries outweighs the effect of interface property. In terms of damage of the material studied, the low strength bonding at the interface could result in earlier damages (or debonding) and consequent earlier softening and failure, compared to the material with high strength bonding. When second phase particles are relatively large and all located at grain boundaries, the hardening effect can be improved and the magnesium alloy shows relatively high flow stress. However, the high hardening effect from the second phase particles could generate high local stress concentration and early damages (or debonding) at the interface, which result in early failure or low ductility of Mg alloys.

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Abstract Title	Simulation of cracks in reinforced concrete beams using extended finite element method including nonlinear material behavior and aggregate interlock stresses
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	<u>Adrian Faron</u>[1], Günter A. Rombach[1] [1]Hamburg University of Technology (TUHH) Email: a.faron@tuhh.de

Abstract

This study presents a comparison between discrete crack simulations using the extended finite element method (XFEM) and tests on single span reinforced concrete beams without stirrups. These investigations aim to determine the different shear force components in a shear crack. For this purpose, representative aggregate interlock approaches were examined in more detail and implemented into the finite element model. The complex material of concrete was modelled using the "concrete damage plasticity" (CDP) model. Basic settings for the simulations are given. Beam tests were used to validate the extended FE-model. There was good agreement in the load-defection curves and in the crack pattern. The different shear force components were determined and compared with the test values. The reasons for the differences were explained. The investigations have shown that the shear force is mainly carried by the uncracked compression zone. Crack friction is small in the ultimate limit state.

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Abstract Title	High Throughput Fatigue Characterization
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Grant West[1] and Derek Warner[1,2] [1] Cornell Fracture Group, School of Civil and Environmental Engineering, Cornell University, Ithaca, NY 14853, USA [2] Canterbury Fracture Group, Civil and Natural Resources Engineering, University of Canterbury, Christchurch, 8041, New Zealand Email: grw66@cornell.edu

Abstract

Damage prediction models for cyclic loading applications are highly sensitive to uncertain input parameters, particularly in scenarios governed by crack initiation. The uncertainty can be addressed by increasing the size of the calibration dataset, yet doing so has remained a long-standing challenge. Traditional methods to collect fatigue failure data that is governed by crack initiation are slow, expensive, and prone to high variability.

Towards addressing this challenge, we present a uniaxial mechanical fatigue testing concept that aims to increase testing throughput by more than an order of magnitude, while maintaining testing cost and consistency with popular standards, ASTM E466 and ISO 1099. After considering various concepts to enhance uniaxial fatigue testing throughput, we focus on a mechanical analysis of the most promising approach. A prototyped design was developed and demonstrated with 39 aluminum 6061-T6511 test specimens subjected to 2 million loading cycles. The performance of the prototype was assessed against the popular standards via numerous strain gauge measurements over the duration of the test and by comparing the failure distribution to a traditional MMPDS fatigue dataset. This work lays a foundation for accelerating the generation of large, reliable datasets that can improve the calibration and predictive capability of damage models.

Abstract Title	Capturing complex fracture propagation using an enriched constitutive modelling framework
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Giang D. Nguyen[1], Ha H. Bui[2] [1] University of Adelaide [2] Monash University Email: g.nguyen@adelaide.edu.au

Abstract

We present a new approach for modelling and capturing challenging complex fracture propagation in quasi-brittle materials. This approach is based on the enriched kinematics of the constitutive equations that allows capturing the evolutions of the embedded localisation band in terms of both size and behaviour. The enrichment at the particle (constitutive) level intrinsically provides the derived constitutive models a length scale and as a result, no ad hoc regularisation in the numerical scheme for Boundary Value Problems (BVPs) is needed. The proposed approach therefore can be straightforwardly applied to any mesh-based or mesh-free methods without requiring any further enhancements. Applications to both Finite Element Method (FEM), and particle-based methods (Smoothed Particle Hydrodynamics – SPH, and the Material Point Method - MPM) are used to demonstrate the potentials and capabilities of the proposed approach in capturing complex fracture propagation in quasi-brittle materials.

Abstract Title	A partitioned computational framework for exploiting damage in stress corrosion cracking of metal matrix composite using phase-field method
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Chaitanya Kandekar[1], Aravinth Ravikumar[2], Daniel Höche[2], Wolfgang E. Weber[1] [1]Helmut Schmidt University / University of the Federal Armed Forces Hamburg, Chair of Structural Analysis, Hamburg, Germany [2] Helmholtz-Zentrum hereon GmbH, Geesthacht, Germany Email: kandekarchaitanya@hsu-hh.de

Abstract

In a metal matrix composite material, stress corrosion cracking (SCC) typically implies pit formation, detachment of matrix and inclusion, pit growth, pit-to-crack transition, and crack development. For example, in an aluminium matrix composite material, inclusions such as ceramic particles are embedded in the relatively softer aluminium matrix to improve its stiffness and strength. However, corrosion can considerably deteriorate the integrity of this composite material by separating the particles from the matrix and facilitating the development of cracks that eventually lead to total failure. In this complex coupled problem, mechanical loading, polycrystalline material, size and shape of inclusion particles, and an aggressive corrosive environment strongly affect pit shape, growth and crack propagation. As a result, assuming inclusion particles are less reactive and non-corrodible, the dynamic connection between the corrosion front and embedded particles reroutes the crack front, leading to intergranular SCC and transgranular SCC.

Furthermore, the analysis of failure by SCC requires a detailed and extensive modelling technique that addresses the impacts of different events, maintains coupled mechanistic interaction, and accounts for scaling effects in both time and space. Simulating such coupled processes in a composite material is very expensive and limited by computational capabilities. This work presents a partitioned computational setup and a multi-phase-field technique employing two independent single-physics solvers connected via an open-source coupling library, preCICE [1]. The model includes the effects of impurities and serves as an extension to the previous work [2, 3]. The proposed computational setup simulates mechanical fracture and dissolution-driven pitting corrosion under varied inclusions and corrosion conditions using two distinct software environments, each with its own set of solver settings and time steps. The potential of the presented model to effectively forecast the progress of both intergranular SCC and transgranular SCC is illustrated through numerical examples utilizing a 2D polycrystalline model that represents the aluminium matrix composite.

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Abstract Title	Phase Field Modeling of Fatigue in Laser-Powder Bed Fusion and Wrought 316L Notched Specimens
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Warem Fokoua Ferdous [1]* and Moritz Braun [1] [1] German Aerospace Center (DLR), Institute of Maritime Energy Systems, Geesthacht, Germany * Correspondence Email: warem.fokouaferdous@dlr.de

Abstract

Physical experiments to determine the fatigue strength of additively manufactured components are time-consuming and expensive. Simulations offer a promising alternative to address this challenge. In this study, phase field simulations were conducted to replicate the fatigue cycles of both additively and conventionally manufactured 316L specimens. The tests included specimens with U- and V-notches. The results revealed a strong dependence of the fatigue cycles on parameters introduced by the phase field simulation method, which correlates with material properties. One of these parameters can be used to account for material- and process-induced influences on real specimens within the simulation. Furthermore, the findings demonstrated that adjusting the parameters properly could align simulation results with experimental data. Additionally, the simulations were able to replicate S-N curves of all specimens, consistent with literature data.

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Venue: National University of Singapore

Abstract Title	A unified temporal-spatial scaling law for hydraulic fracturing of layered heterogeneous rocks
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Quan Wang, Hao Yu, HengAn Wu Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: wq9577@mail.ustc.edu.cn

Abstract

Measuring the effective toughness of fractures in heterogeneous layers remains a challenge due to the complex energy dissipation involved. This work presents a unified scaling law for hydraulic fracture propagation in layered rocks, where fracturing behavior is influenced by both layer thickness and property contrasts across interfaces, leading to non-self-similar propagation over time. The singular integral balance equation is derived by introducing a kernel function that accounts for the varying elastic modulus and a modified load term that incorporates in-situ stress. The layered distribution of elastic modulus and fracture energy is considered through dynamic tip asymptotics. The governing equations and boundary conditions are then nondimensionalized by new characteristic scales of fracture opening, fluid pressure, and fracture length, which are proposed to depict the spatial relationship between the interface and fracture. Its solutions are obtained through a decomposed approach to match the fracture morphology and tip boundary conditions. This model captures a novel time-sensitive propagation mode of hydraulic fracture, jointly dominated by toughness in the tip region and viscosity dissipation at the interface region, especially in multilayer rocks. Consequently, the temporal scale of injection time and the spatial scale of layer thickness are integrated into the characteristic scales. A scaling law is thus proposed to fully consider the variations of elastic modulus, fracture energy, fluid flux, injection time, and layer thickness on propagation behaviors. The law spans the temporal-spatial parameter space within a general framework that quantifies the evolution of viscosity dissipation induced by interfaces, summarizing four fracturing cases: the homogeneous model, single-interface model, multi-layer model, and homogenized model. The proposed law provides a unified measure for modeling hydraulic fracturing of layered heterogeneous rocks with arbitrary thickness and propagation stage.

Abstract Title	Effects of anisotropy and layered heterogeneity on hydraulic fracture propagation in laminated shale: a 3D numerical approach.
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xiao Ke, Hao Yu and HengAn Wu Department of Modern Mechanics, University of Science and Technology of China, Hefei 230027, China Email: sa22005013@mail.ustc.edu.cn

Abstract

Accurately simulating the propagation process of hydraulic fractures is crucial for fracturing control in shale extraction. However, the fracture growth process is significantly influenced by the inherent heterogeneity and anisotropy of shale, particularly its effect of fine-scale variations in lithological properties, which are crucial for fracture network development. This study addresses these gaps through developing a three-dimensional hydraulic fracture propagation model for transversely isotropic shale, incorporating anisotropy in Young's modulus, permeability, and in-situ stress. Through numerical simulations using the cohesive zone model, we accurately characterize fracture propagation behaviors in both length and height directions and the interaction behaviors at bedding planes. Our findings reveal that anisotropy in mechanical properties and permeability significantly influences fracture containment and propagation tendencies in both length and height directions. Additionally, the effect of layered heterogeneity is mainly reflected in the interaction patterns with the bedding plane and its failure mode. The four representative propagation behaviors, namely termination, deflection, cross, and penetration, are used to differentiate the three-dimensional morphological characteristics of fractures. Meanwhile, we identify the key factors that dominate different propagation behaviors and the relationships between these factors, with the relative strength of the bedding plane and the differential in-situ stress being the controlling parameters. This research underscores the importance of considering fine-scale anisotropy and layered heterogeneity in fracturing design to achieve efficient fracture networks, offering valuable insights for optimizing hydraulic fracturing operations.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	On the comparison between mixed stabilized finite element formulations and non-local/gradient-enhanced models for fracture modeling in quasi-brittle materials
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Anselmo Rodríguez-Moreno[1], Juan Carlos Pina[1], <u>Carlos Felipe Guzmán</u>[1] [1]University of Santiago of Chile (USACH), Faculty of Engineering, Civil Engineering Department, Chile. Email: cf.guzman@usach.cl

Abstract

Fracture in quasi-brittle materials is characterized by a Fracture Process Zone, typically defined as a small region surrounding a crack where non-linear phenomena, such as plastic deformation and damage, occur. This region exhibits a softening behavior, displaying a decreasing load-carrying capacity after reaching peak load. This behavior is commonly observed in structural materials like concrete and timber. Accurately modeling this phenomenon can be challenging due to its dependence on various factors, including the type of loading (tension or compression), fiber orientation (particularly crucial for timber), and the presence of a size effect, where the material's behavior changes depending on the structural member's dimensions. Traditionally, displacement-based irreducible Finite Element (FE) formulations have been employed to model the mechanical behavior of concrete and timber structures. However, these formulations exhibit significant drawbacks, such as mesh sensitivity and convergence difficulties, when applied to model softening, localization, and fracture phenomena. To address these limitations, various alternative approaches have been developed in recent years. In this work, two distinct approaches are compared: mixed FE formulations and gradient-enhanced models. In the mixed FE approach, we propose employing two fields, displacement and strain, as primary unknowns within the system. To ensure satisfaction of the *inf-sup* condition, which is associated with saddle point stability in mixed formulations, we utilize the Variational Multiscale Method to incorporate stabilizing terms into the system. For the second approach, we consider non-local micromorphic localizing gradient models with decreasing interactions, which have proven effective in describing damage propagation in quasi-brittle materials such as concrete and timber. This work presents a theoretical and numerical discussion of the advantages and disadvantages of mixed FE formulations and gradient-enhanced models. The performance of each method is evaluated based on its ability to localize strains without mesh dependency, minimize mesh sensitivity, and ensure the stability of the solution field, even when employing low-order interpolation elements and irregular meshes. The potential for extending these approaches to anisotropic material behavior and large strain deformations is also explored.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

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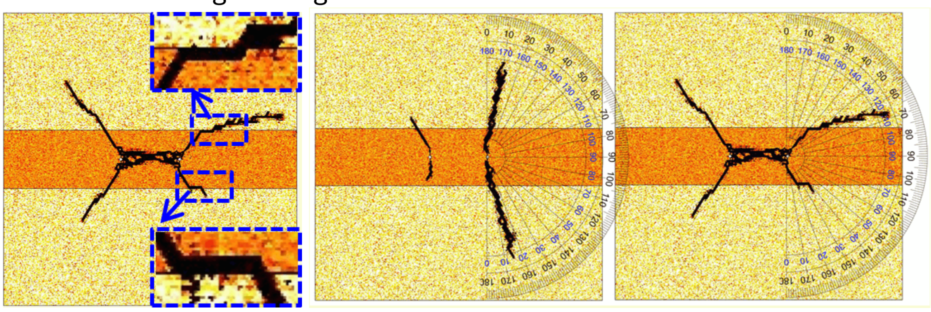
Abstract Title	Interactions among multiple hydraulic fractures revealed by a hydro-mechanical coupled model using continuum damage mechanics (CDM)
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yongjun Yu[1] [1]Taiyuan University of Technology, Taiyuan, China Email: yuyongjun5658@163.com

Abstract

Exploitations of oil-gas reservoirs have been conducted for underground formations of a large depth at present. Increases of hydraulic fracture quantity and stimulated reservoir volume can be achieved by increasing the fracturing wellbore quantity, reducing the spacing of wells prescribed, stages as well as clusters. **However, mutual interactions of fractures relating to sophisticated mechanical problems, lead to reorientation of fracture propagation trajectories, altering actual induced fracture quantities and fracture complexities, thus influencing reservoir stimulation effectiveness and ultimate oil-gas productions.** In this study, a modified fracturing numerical model with coupled single-phase flow-reservoir deformation process is proposed. The model is applied to numerical simulations of mutual interactions among fully three-dimensional hydraulic fractures. Furthermore the fracture interaction in the multi-phase flow field is studied based on a coupled model of oil-water two-phase flow with unsaturated sandstone reservoir deformation. **Both fracture attraction and repelling behaviors are well captured and discussed in this work.** Several key factors influencing fracture interactions in coal bed reservoirs are fully discussed aimed at a rational recognition of the complex fracture interference during reservoir stimulation engineering.



(a) (b) (c)

Figure 1 Multiple fracture repelling

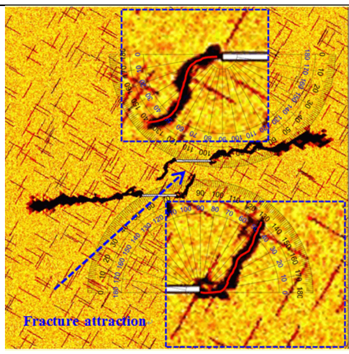


Figure 2 Fracture attractions

Key words: damage mechanics; reservoir stimulations; fracture interactions; stress shadow;

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Dynamic mechanical characterization and validation of Additive Manufactured Copper
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Abstract

Understanding of plastic deformation and fracture behaviour, particularly in high strain-rate scenarios, in additive manufactured copper remains insufficient. This investigation aims to comprehensively explore its mechanical properties through hybrid experimental-numerical methodology and identify strain-hardening and strain-rate parameters. A series of mechanical tests were under both quasi-static and dynamic loading conditions at room temperature. Tensile tests were performed using dog-bone samples over a wide range of strain rates. Direct or inverse methods based on finite element simulations were used to analyse the quasi-static experimental data. Results indicate that, the additive manufactured copper exhibited strain hardening and strain rate sensitivity, with asymmetry observed in tension-compression behaviour. CT scans revealed a higher quantity of defects between adjacent layers compared to defects between layers, resulting in macroscopic anisotropy. Additionally, the building orientation significantly affected the mechanical properties of 3D printed copper. Numerical simulations against experimental results of Taylor impact demonstrated that parameters calibrated using Johnson-Cook constitutive model and fracture criterion effectively capture material deformation and fracture modes under diverse loading conditions, especially at ultra-high strain rates. These findings provide valuable insights into the mechanical properties of additive manufactured copper, facilitating improvements in material design and fabrication process, and further promoting its application in impact scenarios.

MS15- Nonlocal damage mechanics: modeling and computational aspects

Abstract Title	Thermodynamic framework of non-local continuum damage-plasticity model
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yijun Chen[1], Mostafa E. Mobasher[1], Haim Waisman[2] [1]New York University, Abu Dhabi [2]Columbia University Email: yijun.chen@nyu.edu

Abstract

Fracture initiation and propagation in geomaterials are often accompanied by several complex behaviors characters, including localized degradation of physical properties, material hardening and softening, irreversible plastic deformation, brittle-ductile failure transitions, and confining pressure dependency. Therefore, it is crucial to develop a sound theoretical model to realistically predict these sophisticated features involved in the progressive failure process of geomaterials.

We present a novel approach to representing geomaterial failure through a new non-local continuum ductile damage model. The model is based on a thermodynamically consistent definition of constitutive and state laws that account for non-local damage and unrecoverable plastic deformation response. The damage driving force function comprises two key contributions, i.e., the tensile part of the elastic free energy and a portion of the plastic free energy. A non-local integral formulation is employed to regularize the damage variable to address the mesh dependence problem inherent in the local damage model. Additionally, a Newton–Raphson method is utilized to solve the nonlinear system of equations, including the derivation of a non-local damage-plasticity consistent tangent operator. The stress state and consistent tangent operator are updated at the Gauss point level using an implicit elastic predictor and return-mapping algorithm.

A detailed material parameter calibration procedure is performed based on standard laboratory tests, including uniaxial-, biaxial- and conventional triaxial-compressive experiments. Furthermore, the proposed model is applied to model benchmark geomechanics problems, such as proportional low-cyclic tension/compression loads on hexahedron plain concrete specimens and a compacted clay plate under tension loading. The numerical results include the investigations of the effect of various material properties on damage evolution and plastic deformation. Comparisons between modeling results and previously published numerical and experimental data validate the predictive capability of the proposed model. In addition, the model is employed to analyze the energy budget mechanism in frictional shear fracture problems, which provides a physics-based understanding of energy budget in geomaterials fracture, leading to advances in ground improvement and other geotechnical supporting systems.

Abstract Title	Fracture analysis of heterogeneous material with orthotropic properties using ordinary state-based peridynamics
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Hanlin Wang[1], Lei Ju[1], Satoyuki Tanaka[2], Erkan Oterkus[3] [1] Harbin Engineering University [2] Hiroshima University [3] University of Strathclyde Email: hanlin.wang@hrbeu.edu.cn

Abstract

In recent decades, heterogeneous material has shown promising potential in many engineering applications, such as aerospace, biomaterial, marine and electronics. Structures with this type of material may experience various extreme loadings during operation, leading to concerns about the structure safety. The presented research aims to investigate the fracture behaviour of the heterogenous orthotropic material using peridynamics. The ordinary state-based peridynamics, as a nonlocal method with spatial integration algorithm, has superiority in dealing with fracture and damage.

Several numerical cases are conducted in this study as validations. The influence of material gradient on the fracture parameters will be carefully examined. Evolutions of crack under mode-I and mixed-mode loading conditions will be demonstrated, while the crack trajectory and responses from the structure will be discussed in detail. The presented work would like to provide a theoretical support for the engineering designs and applications.

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Date: 16th - 18th July 2025
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Abstract Title	A new damage-failure model for quasi-brittle material: Nonlocal macro-meso-scale consistent damage model and its advances
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jianbing Chen[1,2], Yudong Ren[1,2], Guangda Lu[3] [1]State Key Laboratory of Disaster Reduction in Civil Engineering [2] College of Civil Engineering, Tongji University [3]Department of Civil and Smart Construction Engineering, College of Engineering, Shantou University Email: chenjb@tongji.edu.cn

Abstract

The multiscale characterization and complex mechanisms of the solid fracture process have long been important yet challenging issues in solid mechanics. Despite significant progress over the past 20 years, in particular with the development of peridynamics and phase-field fracture theory which have become the mainstream methods, solid failure, especially in quasi-brittle materials, remains a challenging problem. Recently, a new nonlocal macro-meso-scale consistent damage (NMMD) model with physical-mechanical features of transmission from mesoscopic to macroscopic level, translation from geometric to energetic damage and transformation from discontinuous to continuous deformation, has been proposed (Lu and Chen, 2020a, 2020b) and provided a novel promising two-scale damage analysis framework.

In the NMMD model, in the influence range of each macroscale material point of the continuum, a meso-structure constituting material point pairs is attached so that the damage and fracture on the macroscale is informed from the meso-scale deformation and energy dissipation (Lu and Chen, 2020a; Chen et al, 2024a). In this view, the external loading results in deformation on the macroscale, and in turn leads to the deformation of material point pairs on the mesoscale. When a certain measure of deformation of the mesoscale material point pair exceeds a critical value, two mesoscale material points undergo irreversible separation, leading to the development of mesoscopic damage. The progressive failure of material point pairs on the mesoscale accumulates to form the topologic change of the macroscopic continuum. Therefore, quantitatively the topologic damage can be obtained by the weighted average of mesoscopic damage within the influence domain. Clearly, the topologic damage is essentially the measure of geometric discontinuity on the macroscale. Simultaneous, the mesoscale damage will lead to energy dissipation, and therefore the ratio of dissipated energy to the free energy in the influence domain of a macroscale material point is nothing but the damage in the energy sense charactering the degradation of material on the

macroscale. This bridges explicitly the conversion from the damage in the geometric sense to the damage in the energy (material degradation) sense. The damage in the energy sense can then be inserted into the framework of continuum damage mechanics, resulting in the constitutive law. It is worth noting that this also reveals the physical essence of the energetic degradation function that is widely used in the phase-field models. In this model, the evolution of topological damage has a clear mesoscopic physical mechanism, in other words, it is a mesoscale informed macroscale damage, which ensures the numerical objectivity of the numerical results. Meanwhile, because the definition of topologic damage stems from the mathematical description of the crack, the NMMD model can naturally capture the nucleation, propagation and branching process of cracks without crack tracking strategy and cracking criterions.

Besides static fracture analysis of quasi-brittle material, Lu and Chen (2020a, 2020b) adopted the NMMD model for the quasi-static failure of quasi-brittle materials and dynamic crack branching problem of brittle material (Lu and Chen, 2021). Chen et al. (2021) physically modelled the energetic degradation function based on the embedded two-scale model in the NMMD model. Based on this work, Chen et al. (2024a) and Ren et al. (2024b) conducted the conversion from the damage in geometric sense to the damage in energetic and mechanical sense on the meso scale. Further, Chen et al. (2024b) proposed a unified description of the meso structure of the NMMD. Then, Lu et al. (2024) rigorously established the link between NMMD model and linear elastic fracture mechanics, and showed that the NMMD model can capture the non-constant fracture parameters in experimental observations, which cannot be achieved in the phase-field fracture model in a logical consistent manner. In addition, Lu (2024) calibrated the characteristic length of NMMD model for the PMMA material. Simultaneously, Ren et al. (2023a) decomposed the damage driving force in the NMMD model, and extended the NMMD model to compression (Ren et al., 2024a) and shear (Ren et al., 2023b) failure problems. Ren and Chen (2021) and Lu and Xie (2024) adopted the NMMD model for the stochastic fracture of concrete specimens. The model has been adopted for various problems. For instance, Xia et al. (2024) extended the NMMD model to anisotropic fracture in rocks. In terms of numerical methods, Du et al. (2023) employed the scale boundary finite element method (SBFEM) to solve the NMMD model efficiently, and extended the NMMD model to rate-dependent cracking problem (Zhao et al., 2024). Zhang et al. (2024) proposed an adaptive SBFEM for the NMMD model. Lv et al. (2024a) proposed a discrepancy-informed quadrature scheme for the numerical integration on the influence domain. The NMMD model has also been implemented into commercial softwares such as ABAQUS (Lv et al., 2024b) and COMOSOL (Xue et al., 2024) for multi-physics fracture problems and 3D fracture problems.

Compared with the peridynamics and phase-field fracture model, the NMMD model provides a two-scale damage analysis framework with clear physical-mechanical mechanisms, and is computationally more efficient. Therefore, the NMMD model holds great potential in the solid failure problems, especially in the failure of quasi-brittle materials.

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Abstract Title	FEM simulation of a low-cycle fatigue using a cycle jump algorithm. Application to a DP600 preformed sheet component.
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xiao LIU[1], Carl LABERGERE[1], <u>Houssem Badreddine</u>[1] [1]Université de Technologie de Troyes, LASMIS, 12 rue Marie Curie CS 42060 Troyes, France Email: houssem.badreddie@utt.fr

Abstract

A numerical FEM methodology is proposed, incorporating a cycle jump algorithm to predict the low-cycle fatigue life of mechanical structures and components subjected to various loading paths and initial conditions, including the effect of prior preloading . A fully coupled material behavior model is formulated within the frameworks of continuum mechanics and the thermodynamics of irreversible processes. This model incorporate state variables that account for isotropic and kinematic mixed hardening effects, while incorporating the full coupling with damage based on continuum damage mechanics (CDM). A dedicated cycle integration scheme is introduced to extrapolate mechanical fields through cycle jumps . Numerical simulations of cyclic bending tests on pre-formed component illustrate the significant impact of residual mechanical fields from previous loading on fatigue life prediction.

Abstract Title	Fracture prediction for various sheet metals using enhanced Continuum Damage Mechanics model
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Kai ZHANG[1] Shandong University of Science and Technology Email: kai.zhang@sdust.edu.cn

Abstract

Fracture prediction of sheet metals under various loading conditions is critical for optimizing manufacturing process and ensuring reliable performance in engineering applications. This study proposes an enhanced Continuum Damage Mechanics (CDM) model that captures various physical phenomena leading to material fracture. By incorporating anisotropy, influences of stress state, temperature, and strain rate effect into a unified framework, the model provides an accurate description of the plastic deformation and damage evolution. The proposed constitutive model is implemented into Abaqus/Explicit via user defined subroutine (VUMAT). Calibration of the plasticity and damage parameters is performed through an inverse method based on simple tests. The model is validated through experiments involving different loading paths and strain rates on representative sheet metals. Numerical simulations demonstrate that the proposed model yields better correlation with experimental fracture compared to traditional CDM approaches, particularly under complex stress states. This enhanced predictive capability offers deeper insights into the interplay between plastic deformation and damage progression. As a result, it provides a powerful tool for more reliable design and optimization processes for sheet metal components.

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Abstract Title	Application of a micro-macro elasto-viscoplastic model fully coupled with ductile damage to FEM simulation of metal forming processes
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	K. Cao[1], N. Hfaiedh[2], C. Labergere[1], H. Badreddine[1] [1]Université de Technologie de Troyes, LASMIS, 12 rue Marie Curie CS 42060 Troyes, France [2] De Vinci Higher Education, De Vinci Research Center, Paris, France. Email: naila.hfaiedh@devinci.fr

Abstract

This paper presents a self-consistent micro-macro elasto-viscoplastic model fully coupled with ductile damage, designed to describe the mechanical behavior of polycrystalline face-centered cubic (FCC) metallic materials. The model is based on the β-rule self-consistent approach, considering three damage-affected scales: (i) the macro-scale of the part, (ii) the meso-scale of the grain, and (iii) the micro-scale of the slip systems.
The constitutive equations are formulated within the framework of the thermodynamics of irreversible processes and are expressed at the slip system scale. At this scale, a modified Schmid yield function is introduced, incorporating isotropic hardening and slip system damage. Additionally, a granular kinematic hardening law is defined at the meso-scale and integrated into the β-rule. Different strategies for determining meso- and macro-scale damage fields are proposed and compared. The model is formulated within the finite strain framework, explicitly accounting for the evolution of crystallographic grain orientations.
The proposed model has been implemented into ABAQUS user subroutines. An inverse identification procedure is developed to calibrate the model parameters using an experimental database for the AA7055-T6 aluminum alloy. Finally, the model's validation is performed through simulations of a sheet metal forming process, with results presented and discussed.

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The Fifth International Conference on Damage Mechanics (ICDM5)

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Abstract Title	Calibrating a Damage Model from Lattice Discrete Results
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Gilles Pijaudier-Cabot[1], Julien Khoury[1], Gianluca Cusatis[2] [1]Université de Pau et des Pays de l'Adour [2] Northwestern University Email: Gilles.Pijaudier-Cabot@univ-pau.fr

Abstract

Lattice modelling of quasi-brittle materials such as concrete is a discrete, mesoscale, description of the material in which constitutive relations are prescribed at a lower scale compared to the scale at which continuum-based constitutive relations are written usually. The meso-structure of the material is represented explicitly. Complex nonlinear responses at the macro-scale are obtained, while keeping the constitutive model at the meso-scale simple compared to macro-scale ones. Over the years, lattice models have become more and more efficient. This is the case of the Lattice Discrete Particle Model (LDPM) which will be considered throughout this study. Prediction capabilities and accuracy of LDPM are, in most cases, better than those obtained with continuum-based models. However, solving for equilibrium requires the resolution of a high number of unknowns, and needs extensive computational resources. Reducing the magnitude of the problem is critical for practical implementations. Combining LDPM with classical finite elements is one method. Another one is to upscale the lattice response to a macro-scale continuum one, that can serve as a reference either for calibration of a macro-scale continuum constitutive relation, or used in some data driven approach. In this contribution we consider carefully the first possibility.

We implement first a coarse graining approach based on averaging the equations of conservation to convert lattice results into coarse-grained, continuum-based, stress versus strain responses. Because stresses and strains are coarse-grained independently, their relationship yields a database of macroscopic continuum responses which could also be envisioned to be used in a data driven approach.

Then, these data are used to calibrate a non-local damage model. We start by showing that, although calibration form global responses is possible, the best route is to perform calibration from local quantities (e.g., stress and strain fields). Two lengths enter in the calculation: the coarse graining length and the internal length in the nonlocal model. The first one is obtained from considerations on representative volumes in elasticity. The second one is obtained by constraining the damage model to capture the width of the fracture process zone. Validation on structures of several geometries and several sizes concludes this contribution.

MS16- Damage Modelling of Polymer Composites

ICDM 2025 SINGAPORE
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16 - 18 JULY

The Fifth International Conference on Damage Mechanics (ICDM5)

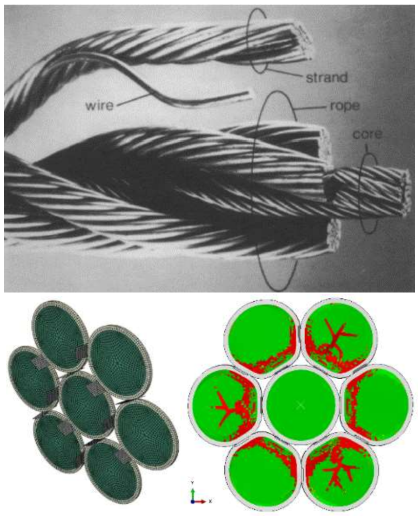
Date: 16th - 18th July 2025

Venue: National University of Singapore

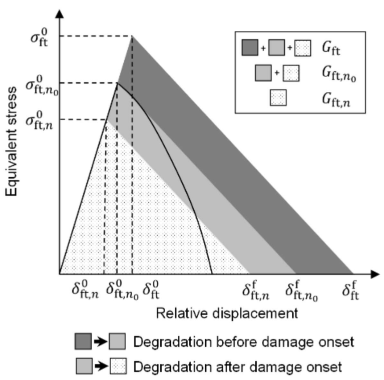
Abstract Title	Numerical Simulation of Fatigue Damage in CFRP Cables Using an Entropy-Based Approach
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yutong LI, Hinako Shiozaki, Ryo Inoue, Jun Koyanagi Tokyo University of Science Email: koyanagi@rs.tus.ac.jp

Abstract

Carbon-fiber composite cables (CFRP cables), owing to their lightweight, high strength, and corrosion resistance, have seen increasing use in bridge engineering applications and tension leg platforms. However, predicting the initiation and progression of damage remains a challenge due to their complex geometries and intricate failure mechanisms. This study focuses on the damage evolution of carbon fiber composite cables under static and cyclic loading, aiming to provide a theoretical basis for evaluating their long-term reliability. Based on the cables' periodic helical geometry, the representative volume element of uni-strand and 7-strand configurations was modeled in Abaqus with periodic boundary conditions. The material behavior was described using a user-defined subroutine. Viscoelasticity was represented using five parallel generalized Maxwell elements, while strength degradation and damage initiation were characterized through an approach that integrates the Hashin failure criterion with thermodynamic entropy generation, as proposed in the authors' previous works. Fatigue simulations for the uni-strand cable were validated against the experimental Goodman curve, whereas the 7-strand model was solely utilized to predict long-term durability. In the uni-strand model, damage under static loading initiates at the center of the cross-section and propagates outward. Under fatigue loading, the initiation region gradually shifts toward the periphery as the mean stress decreases. In the 7-strand model, damage consistently initiates at the contact regions between adjacent side strands.



Conceptual Image of CFRP cables, Geometric Model, and Analysis Results



Numerical Model

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Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	A generic failure model for fiber-reinforced composite laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Xin Lu, Ryo Higuchi, Tomohiro Yokozeki Department of Aeronautics and Astronautics, The University of Tokyo Email: xinlu@g.ecc.u-tokyo.ac.jp

Abstract

This work introduces a generic failure model (GFM) for progressive damage analysis of fiber-reinforced composite laminates. The GFM provides a comprehensive framework to evaluate failure mechanisms, including tensile, compressive, and impact damage, across diverse configurations, laminate layups, and loading conditions. It examines the influence of key design parameters — such as material properties, stacking sequence, and thickness — on failure progression and mechanical performance. Integrated into commercial finite element software Abaqus, the GFM leverages built-in computational capabilities and employs an automated, script-driven parameterization procedure. This approach accelerates numerical analysis and facilitates structural optimization by accounting for the intrinsic features of composite laminates. Utilizing the cohesive zone model and a partition-tie scheme, the GFM captures matrix cracking, inter-laminar delamination, and their strong interactions with high fidelity. The performance of the numerical model is validated through representative case studies on open-hole tension, open-hole compression, and low-velocity impact tests, achieving good agreement with experimental data and demonstrating its accuracy and applicability.

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Abstract Title	Development of Efficient Simulation Framework for High-cycle Fatigue of Composite Laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	ZHOU Shiyin[1], LU Xin[1], HIGUCHI Ryo[1], YOKOZEKI Tomohiro[1] [1]The University of Tokyo Email: zhou-shiyin@g.ecc.u-tokyo.ac.jp

Abstract

Currently, simulations of delamination propagation under high-cycle fatigue loading remain a challenging task in damage mechanics community. In light of this, this study developed an efficient fatigue crack simulation framework by integrating the Paris law, the cohesive zone model, and the improved fatigue damage rate strategy. In this approach, elements whose Failure Index (determined by the quadratic stress criterion) is greater than or equal to 1, but whose damage variable d remains below 1, are classified as "active elements" during the quasi-static damage phase. By summing the total length of these active elements, the cohesive zone length l_{cz} can be accurately determined, thereby effectively capturing damage evolution of crack without resorting to intricate crack-tip tracking. In addition, this improved fatigue damage rate strategy requires only the experimentally fitted Paris law parameters and l_{cz} as input parameters, while explicitly accounting for mesh sensitivity. The proposed fatigue damage rates strategy was implemented into the commercial software ABAQUS via a user-defined subroutine, and the fatigue damage processes under Mode I, Mode II, and mixed Mode loadings were simulated. The results demonstrate that this model can effectively capture the delamination behavior of composites under high-cycle fatigue loading.

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Abstract Title	Influence of fiber waviness on damage mechanisms in CFRTP laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Takayu Nishioka[1], Ryo Higuchi[1], Tomohiro Yokozeki[1] [1]The University of Tokyo Email: nishioka-takayu687@g.ecc.u-tokyo.ac.jp

Abstract

In recent years, the application of CFRTP (Carbon Fiber Reinforced Thermoplastics) has been advancing, particularly in aerospace components, due to its recyclability and high productivity. However, initial manufacturing defects caused by the high processing temperatures and the high flowability of thermoplastics hinder the adoption of CFRTP for large-scale components. In particular, in-plane fiber waviness, which appears on the surface of CFRTP components, is relatively small in scale compared to typical fiber waviness and is known to induce reductions in compressive strength and complex damage behaviors. Although many analytical methods have been proposed to investigate the effects of fiber waviness, detailed modeling of small-scale fiber waviness, such as that observed on the surface of CFRTP components, remains unexplored. Therefore, this study aims to model the complicated damage modes around in-plane fiber waviness in CFRTP laminates in detail and investigate its effect on damage mechanisms. The proposed model was verified by comparing it with experimental data. As a result, when the severity of fiber waviness is small, the damage propagation is predominantly governed by kink band formation. In contrast, as the severity of fiber waviness increases, the influence of damage caused by matrix cracks becomes more pronounced.

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Date: 16th - 18th July 2025
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Abstract Title	Constitutive modeling of damage and healing of vitrimer composites
List of authors & their affiliations with the presenter's name underlined . Provide email contact for the presenter.	Ryo Higuchi[1], Manato Kumada[1], Takayu Nishioka[1], Tomohiro Yokozeki[1], Takaya Suzuki[2] [1] Department of Aeronautics and Astronautics, The University of Tokyo [2] Technical Development Department, Carbon Fiber Division, Teijin Ltd. Email: higuchi@aastr.t.u-tokyo.ac.jp

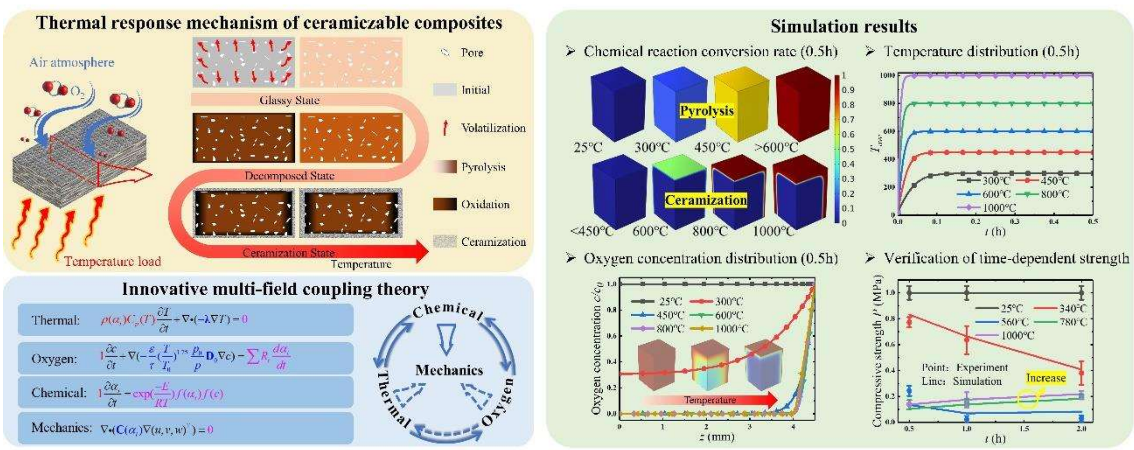
Abstract

Reducing polymer-based material disposal by repair and recycling has become indispensable to achieving sustainable development in society. Recently, vitrimer and its composites have been attracting attention as the next-generation repairable and recyclable structural material. This is because vitrimer shows superior mechanical properties like thermosets at working temperature and re-processibility like thermoplastic above a certain temperature (called topology freezing transition temperature) due to the reversible bonds in its cross-linked network. To achieve the circular usage of vitrimer and its composites, the design scheme to predict the damage propagation, residual strength, and repairability of vitrimer material is necessary. This study aims to develop the constitutive model for predicting damage and healing behaviors of epoxy-based vitrimer, which has disulfide bonds as reversible bonds, and its composites. For the constitutive modeling, mechanical and thermal tests on both intact and repaired vitrimer and its composites were carried out to quantitatively evaluate the residual properties after healing. In particular, two types of fracture toughness tests (double cantilever beam and end notch flexure) on intact and repaired vitrimer composites revealed the mode-dependent repairability of vitrimer composites and provided key findings for modeling.

Abstract Title	Enabling multi-stage high-temperature strength evolution prediction of ceramizable composites using a novel multi-field coupled model
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Zheng Gong[1], Huanfang Wang[1], Chao Zhang[1,*] [1]Northwestern Polytechnical University Email: gongzheng@mail.nwpu.edu.cn

Abstract

Strength varies significantly under high-temperature environment, due to the inherent thermomechanical behavior of the ceramizable material and its coupling with possible chemical reactions. The complexity amplifies for composite materials, considering their multi-phase and multi-scale features, and more importantly, their complicated chemical reactions under high-temperature service conditions. This study proposes an innovative multi-field coupling theory framework for predicting the multi-stage evolution behavior of high-temperature mechanical properties of a ceramizable composite, through incorporating an extended chemical kinetics method, coupled deformation, mass diffusion and heat conduction. The developed model enables direct coupling and simultaneous solving of physical, chemical and thermal variables. It captures well the degradation of mechanical properties for the initial stage and the increase of strength for the later stage, along with the increasing of temperature. The validated model also enables well prediction of time-dependent mechanical properties at high service temperature, with an average error of 8.67% against experimental measured results. The developed method can serve as a general method for the prediction of high-temperature mechanical property of thermal protection composites and structures.



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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Effects of ply-blocking on thin-ply carbon fiber/epoxy laminated composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	R. Ho[1], C.T. Kow[1], K.M. Yeoh[1], K. Raju[1], T.E. Tay[1], V.B.C. Tan[1] [1]Department of Mechanical Engineering, National University of Singapore, Singapore Email: ruth_ho@u.nus.edu

Abstract

The emergence of thin-ply composites has unlocked greater design flexibility, and such composites have been shown to exhibit enhanced strength and fatigue performance relative to standard ply composites [1]. However, thin-ply composites have a higher notch and open-hole sensitivity compared to standard ply composites [2 – 4]. Overall, the ultimate open-hole strength is observed to increase with effective ply thickness [2,3,5], but the load at which the first initiation of damage occurs decreases after a particular ply thickness [3 – 5]. Although computational studies have been performed [3,4], this transition in damage mechanisms as the ply thickness varies has yet to be fully elucidated. As such, this investigation aims to shed light on this transition region between thin-ply and standard ply composites, where the load at the first drop in the force displacement response begins to decrease with increasing ply thickness. Experimental results were obtained with thin-ply prepregs with 3 different ply-block thicknesses, corroborating earlier trends observed [3 – 5], and were used to validate computational models which modelled ply damage and delamination mechanisms, and were based on a combination of Tsai-Wu and maximum stress failure criteria [6].

Introduction

The increased design flexibility and potential weight savings afforded by the emergence of thin-ply composites has led to greater interest in characterizing its properties, with one such area being open-hole tensile properties [1 – 5]. It has been noted experimentally that increasing the ply thickness also increases the ultimate open-hole strength [2,3,5], with different modes of failure observed depending on ply thickness. Thicker plies exhibited a delamination dominated failure, while thinner plies had a predominantly brittle failure mode as observed in experimental results and similar studies [2 – 4]. This is likely due to damage suppression and crack resistance in thinner plies [4]. Also of interest is the first load drop in the force displacement response, which decreases beyond some critical ply thickness [4,5]. Beyond this critical ply thickness, finite element models which do not factor in damage evolution fail to capture this initial damage in thick-ply laminates accurately [3].

Computational studies have been performed to study this trend [3,4] but have not been conducted in tandem with experimental investigations specifically within this transition region, and do not explain the mechanisms behind this transition fully. Thus, this investigation aims to focus on this transition region between thin-ply and standard ply composites by using both experimental and computational studies.

Methodology

Using thin-ply prepreg sheets (CU075NS from Hankuk Carbon), open-hole tensile specimens were fabricated, and the ply thickness was varied by blocking plies together. 3 different layups were used to vary the ply thickness. The first layup used dispersed plies, the second layup blocked 2 plies together and the third layup blocked 4 plies together. The laminate was hand laid, before being cured in an autoclave, and the specimens were waterjet cut to their final dimensions. Open-hole tensile tests were performed according to the ASTM D5766 standard with an Instron 8501 Universal Testing Machine, with interrupted tests to check for any propagation of damage using a CT scan and micrographs.

A progressive damage model using a material property degradation method based on a combination of the max-stress and Tsai-Wu failure criteria [6] was used to model the experiments performed, with cohesive elements used to model delamination.

Results and Discussion

The results of the experimental investigation corroborated earlier findings [3,4], with a greater ultimate open-hole strength with increasing ply thickness and an overall decreasing trend in the first load drop observed. The second layup had a 16% greater open-hole strength compared to the first, while the third layup had a similar strength. For the first drop in the force displacement response, the second layup had a 6% higher load than the first layup, and a 30% higher load compared to the third layup. Specimens with the thinnest ply thickness exhibited a multi-modal failure, with some fiber breakage and fiber pull-out, mainly constrained within a triangular region bounded by the specimen edge and the ±45° fibre directions, whereas specimens with thicker plies showed a delamination dominated failure. Further computational studies carried out also showed this decrease in load with increasing ply thickness at the first onset of damage, along with more delamination and damage. Additionally, with an increase in ply thickness, more free edge delamination was observed to occur before ultimate failure. The computational model was also able to capture these damage mechanisms.

Conclusion

Overall, an increasing ply thickness has experimentally been shown to affect the ultimate open-hole strength, load at which the first onset of damage occurs and the failure mode. Ultimate open-hole strength increases with ply thickness and the load at damage initiation decreases after a certain critical ply thickness. The computational model was able to capture both the decreasing trend in the load at damage initiation, and some of the damage mechanisms seen in experiments. Further study is ongoing to ascertain if any additional damage mechanisms are present and how this transition from a brittle failure to a delamination dominated failure occurs.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Modelling Progressive Damage in Fiber-Reinforced Composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Tong-Earn Tay[1] [1]National University of Singapore Email: mpetayte@nus.edu.sg

Abstract

This presentation discusses multi-fidelity modeling and prediction of progressive damage and failure of notched fiber-reinforced laminates. At the sub-laminate continuum scale, the primary mechanisms of progressive damage are matrix and fiber-matrix micro-cracks, delamination and fiber breakage with strong interactions between mechanisms. Early developments were focused on material stiffness degradation, later also known as smeared crack models. However, when implemented within the finite element framework, these models are found to be mesh dependent. Moreover, the degradation laws require extensive experimental calibration with damage parameters, and modeling delamination growth with it is very difficult or impossible. Later developments of cohesive zone and discrete crack models facilitated the integration of these damage mechanisms into high-fidelity consistent models with minimal sacrifice to the physics of interactions. These advanced models, however, incur high computational costs despite advances in computational power and more efficient explicit finite element modeling. Ideas to adaptively combine high-fidelity and lower fidelity methods are able to mitigate computational costs without sacrificing accuracy. Recently, there is growing interest in the use of machine learning (ML) technology for failure prediction in composites. With appropriate large sets of experimental and simulation training data, it is hoped that ML could accelerate the failure prediction with acceptable accuracy. This presentation outlines key developments and examples in the author's work from smeared crack modeling, discrete crack modeling, fracture and strength characterization of composites, explicit versus implicit finite element implementations, adaptive multi-fidelity modeling, and most recently, research in the use of ML for the prediction of strength and failure strain of open-hole-tension composite laminates.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Design of composite charge based on gas-phase sensitization
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Da-Wei Jia [1], Tao Zhou [1,*], Nan-Nan Zhang [1], Xiao-Fei Qi [1] [1] Xi'an Modern Chemistry Research Institute, Shaanxi Xi'an, 710065, China Email: dwjnwpu@163.com

Abstract

A novel gas-phase sensitized composite charge is developed based on the principles of energy cascade release and gas-phase sensitization. The design comprises an inner layer of thermobaric explosive and an outer layer of mixed fuel consisting of aluminum-based active material and boron-based fuel. Upon initiation, the inner thermobaric explosive undergoes detonation reactions, generating energy that disperses the outer layer material outward. When exposed to air, the outer layer material undergoes combustion, extending the energy release duration of the reaction process. The aluminum-based active materials exhibit detonation-like reactions, releasing substantial chemical energy, while the boron-based fuel decomposes gradually, producing low-molecular-weight combustible gases that enhance the sensitization effect. The results demonstrate that the composite charge achieves optimal performance when the mass ratio of inner to outer layers is 1:2 and the volume fraction of boron-based fuel decomposition products is 0.5%. The gas-phase sensitized composite charge significantly enhances the explosive fireball effect. Compared with conventional thermobaric explosives, it increases the quasi-static pressure impulse of shock waves by up to 3.83 times, indicating superior damage potential in confined environments.

Abstract Title	Structural cohesive elements – enlarging element size for the modelling of delamination in composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Boyang Chen[1] [1]Delft University of Technology Email: b.chen-2@tudelft.nl

Abstract

Cohesive elements have been widely used for the modelling of delamination in composites. Standard cohesive elements are formulated to conform to solid substrate elements. They are placed between solid ply elements to model their separation. Due to the high stress gradients in the cohesive zone, the mesh density must be fine enough to capture accurately the kinematics, stress and energy of the cohesive zone. A common rule of thumb is to have at least two to three elements in the cohesive zone. For the case of Mode I delamination analysis of typical carbon-epoxy composite coupons, this would mean that the element size is often limited to a maximum of 0.5 mm. Such a fine mesh requirement prohibits the straightforward application of cohesive elements for the delamination analysis of large structures such as aircraft wings or wind turbine blades, as the computational cost would be extremely high due to the large number of elements needed for the model.

In this talk, the author will present a series of recent work in his group on a new type of cohesive element, named *Structural Cohesive Element*, for the modelling of delamination with coarse meshes whose element sizes can be *larger* than the cohesive zone, thereby overcoming the cohesive zone limit on mesh density altogether. We have developed both the 2D and 3D versions of the element. Compared against the standard cohesive element, the structural cohesive element models have demonstrated good predictions of delamination with elements as large as 5-mm, a ten-fold increase in element size and a 90% reduction on computational time.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Predicting the mechanical performance of Double-Double laminates
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Gang Yang[1], Jian Shen[1], Wei Yang Zheng[2], Jin Zhao Huang[3], Jia Long Liu[1] [1]Sun Yat-Sen University [2]Harbin Institute of Technology [3]National University of Singapore Email: yangg77@mail2.sysu.edu.cn

Abstract

By increasing the number of repeats n of its [±A/±B]n layup to 8 and above, the Double-Double (DD) laminate behaves like a homogenous material. Recent experimental and simulation results showed that the delamination of DD laminates subjected to impact is also significantly more uniform than conventional Quad laminates. Unlike the Quad laminates where a few delaminations grow more extensively than the rest, the delaminations observed in a DD laminate share a similar size and shape. They are all located near the point of impact like a wood board. With the aid of the experiment, this study conducts numerical simulation for these DD laminates subjected to out-of-plane impact and compression after impact. We further investigate the possibility of developing a simplified FEA model that could predict the mechanical performance of DD laminates quickly and accurately by taking advantage of the uniform damage pattern of DD laminates.

Abstract Title	Experimental and simulated ductile failures of auxetic-honeycomb-based sandwich structures in three-point bending deformations
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Wenting Li*, Kai Soon Fong Singapore Institute of Manufacturing Technology (SIMTech), Agency for Science, Technology and Research (A*STAR), 2 Fusionopolis Way, Singapore, 138634 * Corresponding Author / Email: Li_Wenting@simtech.a-star.edu.sg

Abstract

Because of its lightweight structure with increased strength, high stiffness and improved energy absorption, the Aluminium (Al) honeycomb-based sandwich structure—which is made of a honeycomb core in the center and two thin facesheets—is widely utilized in automotive, marine, and aerospace industries. The sandwich structure with a standard hexagonal honeycomb core is the most common one because the core can be made on a large scale. In comparison with the traditional hexagonal honeycomb core's positive Poisson's ratio, two modified designs, the semi-reentrant and the reentrant honeycomb-like cores, have zero Poisson's ratio and negative Poisson's ratio, respectively, making it easy to obtain single and double curvature surfaces without using post-processing methods.

In this research, sandwich panels with semi-reentrant and reentrant honeycomb-like cores are characterized. The purpose of the study is to explore the crushing deformation and ductile failure of sandwich structures with ultrathin auxetic and non-auxetic honeycomb cells in the out-of-plane three-point bending deformations using computational and experimental methods. Finite element simulations of all flexural deformations are conducted with the mixed Swift-Voce constitutive model which accurately describes plastic deformation. The numerical model is well validated by comparisons of the experimental load-deflection responses and simulation results. Different ductile failure modes are identified, and their behavior and mechanisms are numerically reproduced. In the end, our study advances the in-depth understanding of crushing deformations and failures of Al honeycomb-based sandwich structures and further drives their industrial applications.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Mesoscale modeling of brittle-ductile transition in woven thermoplastic composites
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Y. Tan[1,2], K.M. Yeoh[1], K. Raju[1], V.B.C. Tan[1] [1]Key Laboratory of Textile Science & Technology of Ministry of Education, College of Textiles, Donghua University, Shanghai 201620, PR China [2]Department of Mechanical Engineering, National University of Singapore Email: mpetanbc@nus.edu.sg

Abstract

To accurately model large deformation in woven composites, yarn rotation must be considered. In thermoplastic composites, this is further complicated by matrix plasticity. During forming, non-uniform yarn reorientation causes spatially varying mechanical behavior, challenging to capture computationally. Off-axis uniaxial tests on pre-sheared woven carbon fabrics in a polycarbonate (PC) matrix revealed a brittle-to-ductile transition as yarn orientation angle increased. High-fidelity mesoscale RVE models were developed to study this behavior. An elasto-plastic model for PC and a modified strain-based 3D Hashin criterion for yarns were used. RVEs with small yarn angles (30°, 37.5°) showed brittle, fiber-fracture-dominated failure, while those with larger angles (45°–60°) exhibited nonlinear, ductile behavior due to yarn rotation and matrix plasticity. The matrix underwent large plastic deformation and cracking, while yarns were progressively damaged. Numerical models captured fabric interlocking and were validated through morphology and DIC analysis.

Introduction

Yarn rotation significantly influences the nonlinear shear behavior of fiber-reinforced laminates by increasing apparent stiffness as yarns reorient toward the loading direction under shear and off-axis tension [1,2]. Although high-fidelity RVE models capturing yarn rotation exist [3], they are mostly limited to thermoset composites with minimal plasticity. Existing RVE models for woven thermoplastics focus mainly on on-axis loading, where yarn rotation is negligible [4–6]. However, off-axis loading of thermoplastics—which are gaining popularity for mass production and sustainability [7]—induces substantial yarn reorientation and matrix plasticity, presenting unique modeling challenges.

To address this gap, we propose an RVE model that incorporates both large yarn rotation and matrix plastic deformation. This model is used to investigate the mechanical behavior and failure mechanisms of woven thermoplastic composites under varying degrees of yarn reorientation. Off-axis tensile tests are conducted for model validation.

Methodolgy

Plain weave carbon fabrics with dimensions of 350 mm × 350 mm and an areal density of 210 g/m^2 from Chomarat (France) were sheared to the predefined fabric angles. Plate samples with fabric angles of 60°, 75° and 90° were fabricated, from which tensile test coupons were cut. The loading direction bisects the fabric angles and is referred to as the yarn angle - the angle between the yarn and the direction of tensile load. Five sets of coupons with yarn angles of 30°, 37.5°, 45°, 52.5° and 60° were prepared. Eight layers of carbon fabric separated by 2 layers of PC sheets were stacked together between facing PC sheets. The woven composite samples were then thermoformed in a hot press. Tensile coupons (150 mm × 25 mm) were cut from the thermoformed plates using waterjet.The mechanical load response of woven fabric composites is investigated through RVE analysis. The RVE comprised four homogenized yarns and the surrounding PC matrix pocket.

Results and Discussion

The stress-strain plots for the 30° and 37.5° RVEs displayed high stiffness because of the close alignment of yarn orientation with loading direction. Upon reaching the stress peaks, the plots drop sharply, demonstrating their predominantly brittle characteristics. In contrast, the stress-strain plots for 45°, 52.5° and 60° RVEs exhibit varying degrees of nonlinear shear behaviour. When the angle between the yarn orientation and loading direction is large, the yarn reinforcement contributed less to the mechanical behavior of woven composite, rather the PC pocket played a primary role. Thus, these RVEs demonstrated ductile responses. These are in good agreement with the experiments

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MS17 - Damage and Fracture in Materials Processing, Forming, and Additive Manufacturing

ICDM 2025 SINGAPORE
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16 - 18 JULY

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Progressive damage simulation on additively manufactured curvilinear continuous carbon fiber reinforced polymer composite structures
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Naruki Ichihara[1,2], Ryo Higuchi[2], Sota Oshima[2,3], Masahito Ueda[1], and Tomohiro Yokozeki[2] [1]Nihon University [2]The University of Tokyo [3]Tokyo Metropolitan University Email: ichihara.naruki@nihon-u.ac.jp

Abstract

Additive manufacturing for continuous carbon fiber reinforced thermoplastics (AM-CFRTP) offers curvilinear fiber steering, which adds functionality and performance to composite structures. However, AM-CFRTP has unique defects that restrict its widespread use in industrial applications. Although there are many developments and research to enhance the microstructure of AM-CFRTP, there has been little investigation into virtual testing to ensure structural reliability. This study proposes a progressive damage analysis model for AM-CFRTP based on the continuum damage mechanics. A specimen with curvilinear fiber steering was manufactured using the 3D printing process. A finite element analysis (FEA) model was defined to represent the 3D-printed specimen. The experimental result observed a non-linear behavior, and the FEA model predicted this behavior. The extended finite element analysis was also adopted to predict the ultimate failure with splitting between paths.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Analytical Considerations in the Evaluation of Adhesive Properties of CFRP
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yuto Masaki[1], Sohta Oshima[2], Ryo Inoue[1], Jun Koyanagi[1] [1]Tokyo University of Scienece [2]Tokyo Metropolitan University Email:8221094@ed.tus.ac.jp

Abstract

CFRP (Carbon Fiber-Reinforced Plastic) is known for its characteristics such as high strength, chemical resistance, corrosion resistance, and light weight, and is mainly used in the aerospace industry for structural components of aircraft. Therefore, the bonding technology between CFRP materials is an essential technology for adapting aerospace materials to CFRP. A new technique being researched for this purpose is adhesive bonding. Currently, thermosetting CFRP is used as a material for aircraft, but if some of it could be replaced with thermoplastic CFRP, it would offer advantages in terms of recyclability, moldability, and manufacturing cost. In other words, we need to establish bonding technology between thermoplastic and thermosetting CFRP, which is the ultimate goal of this study.

Evaluation of adhesive bonding can be done in terms of strength and toughness. Strength evaluation focuses on the occurrence of damage, while toughness evaluation focuses on the progression of damage. Both are important indicators, with the single lap shear test being a representative method for strength evaluation and the DCB (Double Cantilever Beam) test being one of the representative methods for toughness evaluation. However, the single lap shear test only provides the apparent shear strength and does not yield the true adhesive bonding strength. This is because the shear force is kept constant, and the complex stress state is ignored, meaning that stress distribution cannot be considered. It is known that there is a significant difference between the bonding strength obtained from the single lap shear test and that obtained from the single lap shear analysis, which considers the complex stress state. By using FEM (Finite Element Method), we are clarifying the stress distribution that cannot be obtained from the test. First, This study aims to perform a DCB analysis to determine whether toughness can be accurately evaluated through this analysis, as well as to perform a single lap shear analysis to determine whether strength can be accurately evaluated using this method.

First, a DCB analysis was performed using FEM. In this analysis, cohesive elements were introduced as adhesive layer, the maximum damage was incorporated, and the fracture

energy was set to 0.3 kJ/m^2. A load-displacement curve was obtained from the analysis, and the fracture toughness value was calculated to check if it matched the set fracture energy. The modified compliance calibration method was applied to determine the fracture toughness value. This method allows for the calculation of fracture toughness without measuring the crack length, providing a more accurate fracture toughness value. Since the fracture toughness value calculated using the modified compliance calibration method matched the fracture energy, it was confirmed that toughness evaluation using the DCB analysis can be performed accurately.

Next, a single lap shear analysis was also performed using FEM. In the single lap shear analysis, the same thickness of cohesive elements introduced in the DCB analysis was used, and Quads damage was incorporated. The main difference between the Max damage and Quads damage is whether or not the complex stress state is considered. By performing the single lap shear analysis, the complex stress state is taken into account, allowing for the determination of the true bonding strength. In this analysis, it was confirmed that the material fails at the strength set in the FEM, and it was made clear that strength evaluation can be performed accurately.

Based on the above, the modified compliance calibration method was applied in the DCB analysis to calculate the fracture toughness value. However, a limitation of this method is that while it allows for toughness evaluation, it is not suitable for strength evaluation. When evaluating materials, strength is generally more practical and widely used than toughness. Therefore, we need to clarify the correlation between toughness and strength in order to enable strength evaluation as well. At this point, we hypothesize that if the strength is doubled, the toughness will increase fourfold, meaning that toughness increases by the square of the strength. It is necessary to verify whether this assumption holds true through FEM analysis. If this can be confirmed, it will be possible to link toughness and strength, making it easier to evaluate materials using both indicators.

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The Fifth International Conference on Damage Mechanics (ICDM5)
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Abstract Title	Fatigue Life Evaluation of Single Lap Adhesive Joints Based on Entropy Damage Modeling
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Abstract

Carbon fiber-reinforced composites (CFRPs) are attracting attention in the aerospace and automotive industries due to their superior specific strength and specific stiffness. In recent years, the demand for durable and sustainable products has increased in consideration of environmental concerns. However, current technologies are not fully capable of accurately predicting the fatigue life of CFRP. As a result, even products that are still usable often need to be retired prematurely for safety reasons. To address this issue, this study aims to develop a fatigue life prediction model based on entropy damage modeling. When constructing structures from CFRP components, the strength of adhesive joints significantly influences the overall structural integrity. This research focuses on single-lap adhesive joints and investigates the relationship between entropy changes and fatigue life under cyclic loading through numerical simulations using the general-purpose finite element analysis software Abaqus/Standard.

Abstract Title	Controlling hot cracking in matrix composite coatings produced by laser surface cladding
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Roya Darabi[2], Erfan Azinpour[2], Ana Reis[2], Jose Cesar de Sa[1,2] [1]INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering, [2]Faculty of Engineering, University of Porto (FEUP), Campus FEUP, Rua Dr. Roberto Frias, 400, Porto, 4200-465, Portugal email: cesarsa@fe.up.pt

Abstract

The rising demand for high-performance components in critical industries such as aerospace, medical devices, and micro-motors has accelerated the advancement of additive manufacturing (AM) techniques to fabricate and repair complex parts with superior material properties. Among these methods, laser cladding stands out as a leading AM technology capable of creating durable, high-quality coatings with customized properties tailored to specific operational needs. This research focuses on tungsten carbide (WC)-reinforced nickel-based metal-matrix composites (MMCs), known for their remarkable hardness, wear resistance, and thermal stability. However, challenges such as thermal cracking, porosity, and residual stresses—stemming from mismatched thermal expansion between WC particles and the Ni-based matrix—pose significant limitations, particularly for intricate structures.

To mitigate these challenges, several approaches have been explored, including optimizing process parameters, modifying powder compositions, and employing advanced techniques like electromagnetic field application and ultrasonic vibration during cladding. Recent developments in computational modelling, specifically phase-field fracture models, have deepened our understanding of thermal cracking and defect formation in MMC coatings. These models enable detailed analysis of crack initiation, propagation, and the influence of process parameters on microstructure evolution and mechanical properties.

This study integrates a fully coupled phase-field fracture model with thermomechanical analysis to investigate laser cladding of WC–NiCrBSiFe coatings. The analysis captures the thermal history, cladding morphology, and real-time crack behaviour during solidification, offering insights into the interplay between WC content, hardness, toughness, and the risk of hot cracking. Findings reveal that optimal performance is achieved at approximately 30 wt% WC, where coatings exhibit excellent hardness and wear resistance with minimal defect formation. Beyond this threshold, the

brittle nature of the carbide-reinforced matrix leads to reduced mechanical performance and increased residual stresses, elevating the risk of hot cracking.

This research provides actionable guidance for minimizing defects and optimizing process parameters to enhance coating performance, facilitating the production of robust and reliable components for demanding applications. By advancing computational modelling techniques and delivering practical insights into the laser cladding process, this work contributes to the development of improved coating solutions for critical industries and promotes further innovation in additive manufacturing technologies.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Advanced Numerical Methods for Multiscale Crystal Plasticity Simulation of Surface Defects
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	<u>Vincent Chiaruttini</u>[1], Christophe Bovet[2], Marie Bouyx[2,3], Vincent Bonnand[2], Julien Réthoré[3], Nicolas Gicquel[4], Aurélien Vattré[2], [1]Safran Tech, Paris-Saclay, France [2] ONERA, Université Paris-Saclay, France [3] Nantes Université, Centrale Nantes, CNRS, GeM, UMR 6183, France [4]Safran Aircraft Engines, Villaroche, France Email: vincent.chiaruttini@safrangroup.com

Abstract

Understanding the evolution of cracks and defects in metallic materials at the microstructural scale presents significant challenges. These challenges include the realistic modeling of crystal plasticity, addressing large-scale problems involving thousands of grains in realistic specimens or mechanical structures, accounting for defects and microstructural discretization, and evaluating representative driving forces behind failure phenomena.

To tackle these issues, this work integrates several key advancements:

1. **Crystal Plasticity Modeling**: A finite strain dislocation density-based model incorporating geometrically necessary dislocations to account for grain size effects.
2. **Adaptive Discretization Techniques**: Finite element methods enhanced by robust mesh intersection and adaptive remeshing for improved accuracy and computational efficiency.
3. **High-Performance Domain Decomposition Solvers**: A grain-based partitioning approach combined with an iterative multi-preconditioned solution process.

This integrated methodology allows performing 3D simulations of fatigue crack initiation and propagation in localized zones where surface defects may form during manufacturing. The simulations, which explore the impact of grain sizes ranging from 10 µm to nearly 1 mm, are compared with some experimental fatigue tests on Inconel 718 specimens, providing insights to improve the modeling of small crack growth regimes under fatigue loading at the microstructural scale.

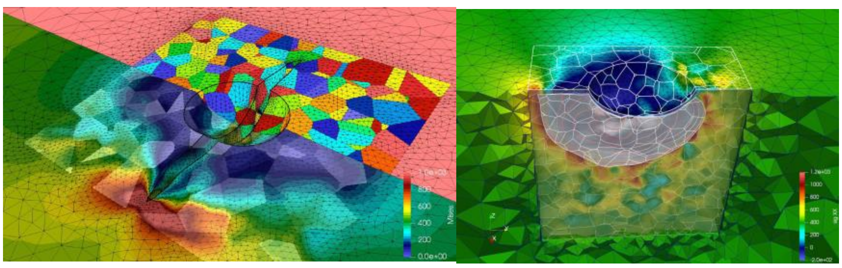

Figure 1. Representation of a microstructural patch with a fatigue crack growth in a spherical surface defect.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025

Venue: National University of Singapore

Abstract Title	Influence of loading path on ductile fracture nucleation based on full-field FE modelling of heterogeneous microstructure
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Abstract

Manufacturing processes often result in complex multiaxial and non-monotonic loading paths, posing significant challenges for the prediction of ductile damage. This study addresses ductile damage at the mesoscale using full-field finite element modeling to simulate heterogeneous microstructures. These microstructures, comprising a matrix and inclusions, are meshed using a body-fitted mesh adaptation technique [1] based on X-Ray laminography images [2]. Local failure criteria and automatic remeshing [3] are employed to model the nucleation, growth, and coalescence mechanisms associated with ductile fracture.
While growth and coalescence have been extensively studied over the past decades, nucleation mechanisms remain less explored [4]. This work focuses on the influence of stress states on nucleation mechanisms, particularly under loading paths representative of manufacturing processes. Special attention is given to varying loading paths that converge to the same final stress state configuration, providing new insights into the role of stress history in ductile fracture.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	A CDM-like constitutive law with cohesive cracks to realize change of fracture behavior in ductile-to-brittle transition temperature
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Seishin Matsui[1], Yuichi Shintaku[1], Kenjiro Terada[2] [1] University of Tsukuba [2] Tohoku University Email: s2420895@u.tsukuba.ac.jp

Abstract

The contribution of this study is to propose a continuum-damage-model-like (CDM-like) constitutive law by combining a cohesive zone model and a ductile fracture model to realize change of fracture behavior at ductile-to-brittle transition (DBT) region. In low temperature, brittle cracks rapidly propagate in the parallel direction to cleavage plane without the plastic deformation due to the increase of yield strength in contrast to the decrease of tensile strength and fracture toughness. The change of stress release process due the propagation of brittle cracks is represented throughout the local equilibrium state between principal stresses and cohesive tractions that are determined by a cohesive zone model. On the other hand, in room temperature, ductile cracks develop from the nucleation, growth and coalescence of the voids along with plastic deformation. Development of ductile cracks is realized by the ductile fracture model as the shrinkage of yield surface along with the increase of voids. Moreover, in DBT temperature, ductile cracks initially develop and turn into brittle cracks as a result of the decrease of fracture toughness during the ductile fracture, which leads to the decrease in cross-sectional area of the specimen by the nucleation and growth of the voids. In our proposed constitutive law, DBT behavior is represented by incorporating void volume fraction into the critical energy release rate of a cohesive zone model. Additionally, the changes of plastic hardening in law, room, and DBT temperature are approximated by Voce hardening law which depends on temperature. The capability of our proposed constitutive law is demonstrated by comparison with experimental results of compact tension specimens in low, room, and DBT temperature.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Comparative study on CDM-like constitutive laws combined with Tresca-type and Mises-type yield functions
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Yuichi Shintaku[1], Kenjiro Terada[2] [1]University of Tsukuba [2]Tohoku University Email: **shintaku@kz.tsukuba.ac.jp**

Abstract

This study presents that CDM-like constitutive laws combined with Tresca-type and Mises-type yield functions are compared to realize shear band that develops into shear-lip fracture under low or negative stress triaxiality state. The CDM-like constitutive laws are developed by a hyper-elasticity based plastic model with the use of the deformation gradient multiplicatively decomposed into separation-induced, elastic and plastic parts. The elastic–plastic deformations along with the isotropic hardening are represented by a Hencky-type model combined with the Tresca-type or Mises-type yield functions, respectively. In addition, the strain softening at the strain localization are realized by the introduction of shear-indued damage variable into both yield functions as the shrinkage of the yield surfaces. The evolution of the shear-induced damage variable is represented by the damage-loading function corresponding to the plastic energy release based on thermodynamics. On the other hand, the stress release process caused by flat fracture is realized by cohesive traction separation law and the assumption of the local equilibrium state between the principal stress and cohesive traction. By comparing with experimental results, the difference of the numerical results of the CDM-like constitutive laws with Tresca-type and Mises-type yield functions are demonstrated throughout various types of specimens under different stress states.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Environment-force-dependent damage behaviors and performance of the high-strength aluminum alloy friction stir welding joints
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Mei Zhan[1], Weifeng Xu[1], Hongjian Lu[1], Yanfei Wang[1] [1] Northwestern Polytechnical University Email: zhanmei@nwpu.edu.cn

Abstract

Friction stir welding (FSW), is one of most promising high-quality manufacturing technologies for high-strength aluminum alloy structural components in aerospace industry. The aircraft structures inevitably service under complex environments and force action. Thus excellent damage behavior and performance of the joint under complex service conditions are needed in order to achieve engineering applications of FSW instead of riveting. This work shows some typical failure behaviors of the high-strength aluminum alloys FSW joints under the service environment and force, including the stress corrosion sensitivity, creep-fatigue behavior, low cycle fatigue damage behaviors corrosion induced-tensile property degradation and tribocorrosion behavior. The damage mechanisms and their correlation with the typical microstructural heterogeneity of the joints are presented. This research provides valuable insights for understanding the environment-force-dependent damage behaviors and performance of the high-strength aluminum alloy friction stir welding joints.

Abstract Title	Formability of multiphase materials – a computational micromechanics study
Authors	Vahid Rezazadeh, Marc Geers, Johan Hoefnagels, Ron Peerlings Department of Mechanical Engineering Eindhoven University of Technology Netherlands Email: r.h.j.peerlings@tue.nl

Abstract

Multiphase material designs generally aim to achieve combinations of properties which are contradictory. A prominent example are dual phase steels, which have a high strength, but are also sufficiently ductile to undergo forming operations. The effective properties of such materials apart from the properties of the underlying phases also depend on the microstructure, i.e. the volume fractions, grain/particle size and morphology of the phase distribution. Micromechanical modelling and simulation has become an indispensable tool for the design of microstructures. In this contribution we demonstrate how highly idealised models of the microstructure, combined with simple damage models, may be employed to obtain generic answers to research questions surrounding the materials design. Specific questions which we aim to answer in this study are: (i) How do pre-existing defects affect the strength and ductility of multiphase materials? (ii) What determines the outcome of the competition between global and local ductility? (iii) How does formability of these materials depend on stress state – in particular on stress triaxiality and Lode angle? The answers obtained to these questions may contribute to optimised designs and new classes of materials.

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The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
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Abstract Title	Reliability Analysis Framework for Rail Joint Wear under Stochastic Parameters Based on Transient Rolling-Sliding Contact in Explicit Finite Element Method
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Tao Liao[1], Haozhe Li[1], Jingmang Xu[1] [1]Southwest Jiaotong University Email: liao1695631052@163.com

Abstract

This paper proposes a research framework to address the issue of enhanced wheel-rail impacts and wear defects in the bonded insulated rail joint (bonded-IRJ) area caused by structural irregularities. The wear patterns near the bonded-IRJ are complex, characterized by both noticeable short-wave and long-wave irregularities (as shown in Fig. 1). Existing studies reveal that rail-end impacts result in complex wheel-rail contact behaviors, including significant increases in wheel-rail forces and contact patch sizes. Due to the inherent structural instability in the joint area, such as the low strength of bonding pads and uneven joint stiffness, this study focuses on analyzing the wheel-rail dynamic response and wear evolution characteristics under complex stochastic operating conditions.

Fig.1. In-service bonded insulated rail joint with obvious rail wear.

In the selection of random variables, multiple physical uncertainties influencing the wheel-rail contact dynamics are considered, including wheelset axle load, running speed, lateral contact position, rail cant, traction coefficient, wheel-rail friction coefficient, and the vertical and longitudinal stiffness and damping of both the suspension and fastening systems. Since the finite element (FE) model does not account for lateral dynamic coupling effects, the lateral stiffness and damping parameters of the suspension and fastening systems are not treated as stochastic variables. Instead, lateral constraints are applied to the wheel-rail system. Table 1 provides the stochastic variables and their probability distribution characteristics used in the wheel-rail impact transient dynamic model (as illustrated in Fig. 2). This framework lays the foundation for quantifying the influence of uncertainties on wheel-rail dynamics and wear behavior in bonded-IRJ regions under stochastic conditions.

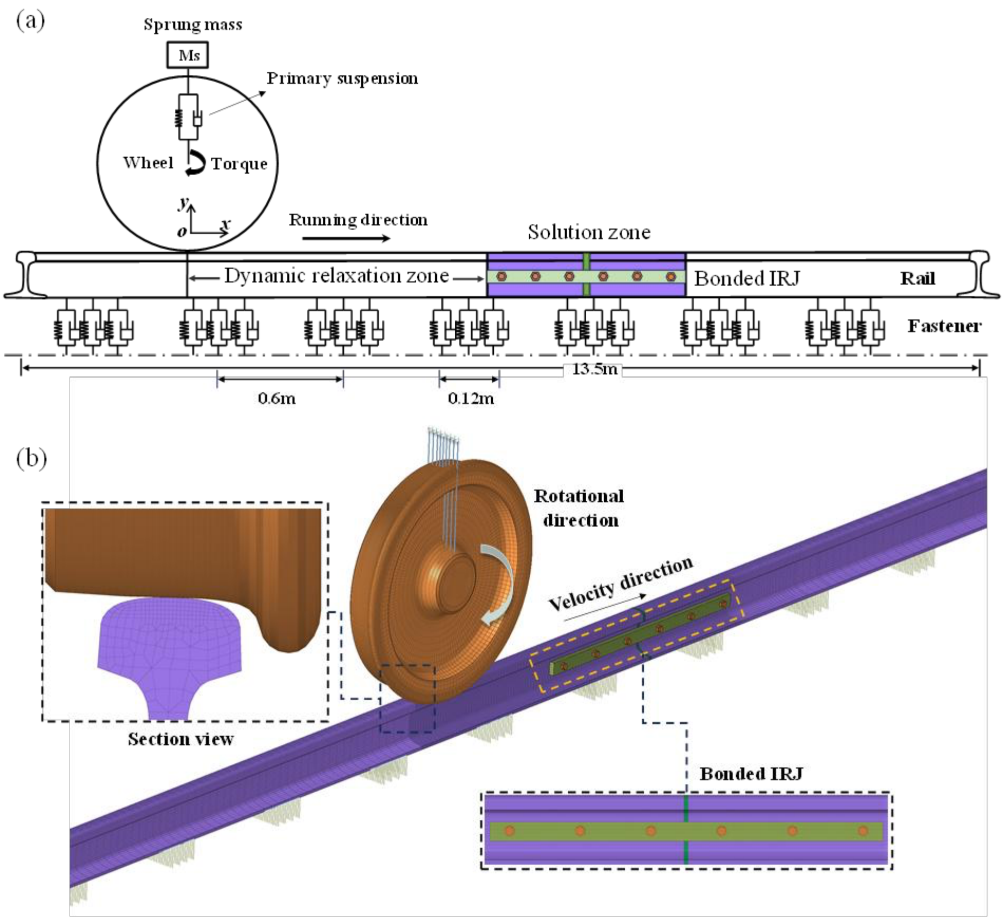

Fig.2. Explicit FE model of wheel-rail impact contact at a bonded insulated rail joint. (a) Model diagram (b) 3D explicit FE model.

Table 1. Probability distribution characteristic parameters of wheel-rail impact transient dynamic model.

Variable name	Stochastic parameters	Unit	Mean	Coefficient of variation	Distribution type
N	wheelset axle load	t	14	0.05	Normal
v	running speed	km/h	280	0.1	Normal
d	lateral contact position	mm	0	300	Normal
rc	rail cant	/	1:40	0.005	Normal

Tc	traction coefficient	/	0.15	0.05	Normal
μ	wheel-rail friction coefficient	/	0.3	0.1	Normal
ks_v	vertical stiffness -suspension	MN/m	0.88	0.05	Normal
cs_v	vertical damping -suspension	kN·s/m	4	0.05	Normal
ks_l	longitudinal stiffness - suspension	MN/m	1.8	0.05	Normal
cs_l	longitudinal damping - suspension	kN·s/m	4	0.05	Normal
kf_v	vertical stiffness -fastener	MN/m	27	0.05	Normal
cf_v	vertical damping -fastener	kN·s/m	40	0.05	Normal
kf_l	longitudinal stiffness -fastener	MN/m	30	0.05	Normal
cf_l	longitudinal damping -fastener	kN·s/m	40	0.05	Normal

This study utilizes stochastic parameter analysis to quantify the impact of various uncertainties on wheel-rail dynamic responses and wear evolution. By incorporating multi-objective optimization methods, a quantitative theoretical framework is developed to support the optimized design and maintenance of wheel-rail systems in the bonded insulated rail joint (bonded-IRJ) area. This approach provides valuable insights into improving the performance and reliability of bonded-IRJ regions under complex operating conditions.

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The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Rolling contact fatigue damage on tooth surface evolution modeling and in-situ dynamic monitoring
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Abstract

The gear transmission system (GTS) is one of the core components of the power transmission chain in aero-engines. During the service life of an aero-engine, rolling contact fatigue (RCF) failure on the tooth surface, such as spalling, occasionally occurs, leading to significant economic losses and even catastrophic consequences. To investigate the RCF mechanism of the GTS in aero-engines, extensive ground-based experimental studies are required. However, new types of aviation gears exhibit a relatively high level of reliability in ground-based experiments. It is barely possible to induce RCF on the tooth surface even after thousands of hours of experiments under the service conditions of the GTS. Moreover, during this process, the performance of the GTS shows no significant changes, which poses substantial challenges for exploring the RCF mechanism of the system through ground-based experiments. To tackle this issue, this study proposes a tooth surface micro-damage evolution model based on crystal plasticity to predict the evolution of RCF damage, such as the initiation of microcracks and the propagation of short cracks. Subsequently, based on the proposed model and the geometric profile of the tooth surface, an in-situ X-ray diffraction (XRD) equation for damaged tooth surfaces is derived to reveal the evolution of XRD spectra under various RCF damage conditions. Finally, an in-situ XRD device for gear tooth surfaces is designed to conduct dynamic in-situ monitoring of RCF damage on the tooth surfaces during the experimental process of the GTS. Based on the results of dynamic monitoring of RCF damage evolution, it is expected to address the challenges in exploring the RCF patterns of GTS during ground-based experiments. The proposed method holds significant value in reducing the total time and cost of GTS experiments and enhancing the service reliability of the GTS.

The Fifth International Conference on Damage Mechanics (ICDM5)

Date: 16th - 18th July 2025
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Abstract Title	A crack prediction model using stress-based variational analysis for composites with ply discontinuities
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	M. J. Mohammad Fikry[1], Vladimir Vinogradov[2], Shinji Ogihara[1] [1]Tokyo University of Science [2] Newcastle University Email: fikry@rs.tus.ac.jp

Abstract

In practical industrial settings, achieving a cost-effective optimal design often involves cutting prepregs at certain locations, which leads to the presence of ply discontinuities in the laminates. While composite laminates with continuous fibers are strong and stiff, the introduction of ply discontinuities can create stress concentrations, potentially causing damage and reducing their mechanical properties. Consequently, it is crucial to evaluate the impact of ply discontinuities on the mechanical properties of laminates and their damage behavior. In this study, a variational analysis approach was employed to determine the stress state in a laminate with ply discontinuities under loading conditions. This work extended the applicability of the variational approach, originally developed by Hashin, to analyze laminates with alternating materials in the longitudinal direction. The extended version of this analysis accommodates arbitrary N-region problems, specifically addressing laminates with ply discontinuities where cracks can form at arbitrary locations within resin-rich regions. To analyze a laminate with a resin-rich region associated with ply discontinuities, the problem was formulated as a laminate divided into several subregions along the longitudinal direction. The stress analysis, based on the principle of minimum complementary energy, was used to calculate the energy release rate associated with crack formation in the resin-rich region. This critical energy release rate was then utilized to predict the crack onset stress in laminates with varying numbers of discontinuous plies and lengths of resin-rich regions. This study presented both energy-based and strength-based criteria for predicting cracking, providing a comprehensive framework for evaluating the mechanical behavior of laminates with ply discontinuities.

ICDM 2025 SINGAPORE
NATIONAL UNIVERSITY OF SINGAPORE
16 - 18 JULY

The Fifth International Conference on Damage Mechanics (ICDM5)
Date: 16th - 18th July 2025
Venue: National University of Singapore

Abstract Title	Anisotropic machinability of additively manufactured Inconel 718: numerical insights into microstructural influence
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Jiaming Zhan National University of Singapore Email: zhanscut@outlook.com

Abstract

Inconel 718, a high-performance Ni-Cr-Fe austenitic superalloy, is extensively utilized in aerospace and engineering due to its exceptional mechanical properties. However, its additive manufacturing (AM) process, specifically via laser powder bed fusion (LPBF), induces complex microstructures that lead to anisotropic mechanical behaviors and challenges in post-processing. These microstructural complexities, arising from rapid solidification and non-equilibrium phenomena, significantly influence damage evolution and deformation mechanisms during machining. This study explores the anisotropic machinability of LPBFed Inconel 718 through experimental and numerical approaches. Micro-indentation and micro-cutting tests reveal directional differences in mechanical properties, while material characterization techniques elucidate the relationship between microstructural anisotropy and cutting behavior. Molecular dynamics (MD) simulations were utilized to model dislocation activities and strain localization, offering insights into the multiscale mechanisms underlying damage and plastic deformation.The findings enhance understanding of the interplay between AM-induced microstructures and mechanical performance, offering critical guidance for optimizing hybrid additive/subtractive manufacturing processes and improving the machinability of Inconel 718 components.

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Abstract Title	Damage and fracture in the deformation of materials and deformation-based manufacturing
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Abstract

Deformation of materials and deformation-based materials processing are one of the most practical engineering activities and an efficient materials processing process, respectively. The latter, on the other hand, is widely employed to fabricate net-shape or near-net-shape parts via plastic deformation of materials. In this process, the design of deformed parts, deforming process and tooling, defect prediction and avoidance, and product quality assurance and control are becoming more and more critical. All of these activities need to consider the damage and fracture in the deformation of materials. Scientific insights into the formation and occurrence of damage and fracture, and an in-depth understanding of their mechanisms and behaviours are crucial in terms of their prediction, control and avoidance. In this talk, the mechanisms of the initiation, coalescence, and growth of voids in the deformation of materials, the formation and occurrence of damage and fracture, and their mechanisms, behaviours, and prediction and avoidance via experiment and simulation will be presented from the aspects of state-of-the-art in damage and fracture research.

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Abstract Title	Investigation of interface microvoid growth and evolution of bimetallic bonding process for carbon steel/stainless steel
List of authors & their affiliations with the presenter's name underlined. Provide email contact for the presenter.	Chaoyang Sun[1,2], Lianjing Hao[1], Huijun Liang[1], Lingyun Qian[1,2], Chunhui Wang[1,2] [1] University of Science and Technology Beijing [2] Beijing Key Laboratory of Lightweight Metal Forming Email: suncy@ustb.edu.cn
Abstract	

Investigating the formation and evolution of voids during the solid-phase bonding process of bimetallic materials contributes to achieving high-quality, fine-pitch, and high-density connections in composite structural materials. Extensive and in-depth research has been conducted on the bonding process of bimetallic materials using various diffusion theories and damage mechanics methods to predict behaviors such as interface bonding, element diffusion and void closure. Based on Gibbs-Thompson diffusion theory and damage mechanics, this work establishes a microvoid growth and evolution model for carbon steel/stainless steel during bimetallic solid-phase bonding process, which incorporates the effects of different mechanisms on interface void evolution, including the local plastic deformation mechanism, viscoplastic flow mechanism, and diffusion bonding mechanism. The model can predict the interface bonding rate of bimetallic materials under large deformation conditions and reevaluates different mechanisms contributions to the void evolution process. The influence of changes in interface diffusion coefficients and stress states on the void closure behavior of the bimetallic bonding interface is discussed. Additionally, the effects of different deformation parameters and initial void sizes on the interface bonding rate of bimetallic materials are investigated. The results show that the void size and distribution predicted in the model are consistent with the experimental results. Compared with previous models, this model demonstrates superior prediction accuracy and reliability. Therefore, revealing the evolution mechanism and regulation method of microvoid expands the industrial application scenario of bimetallic composite bonding.