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June 10 – 12, 2026

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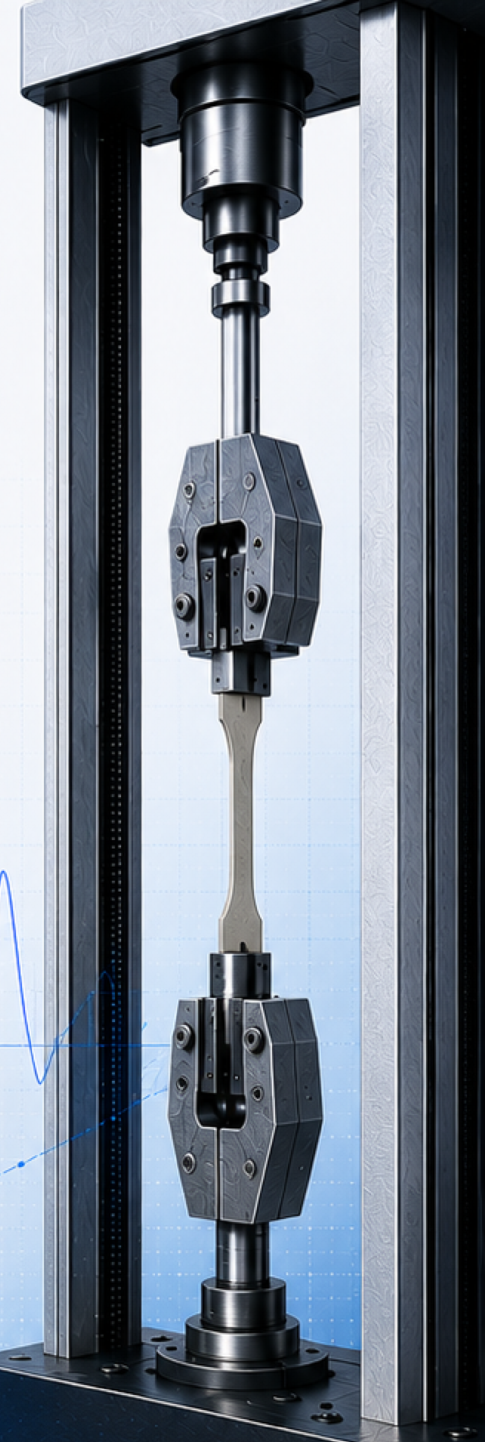

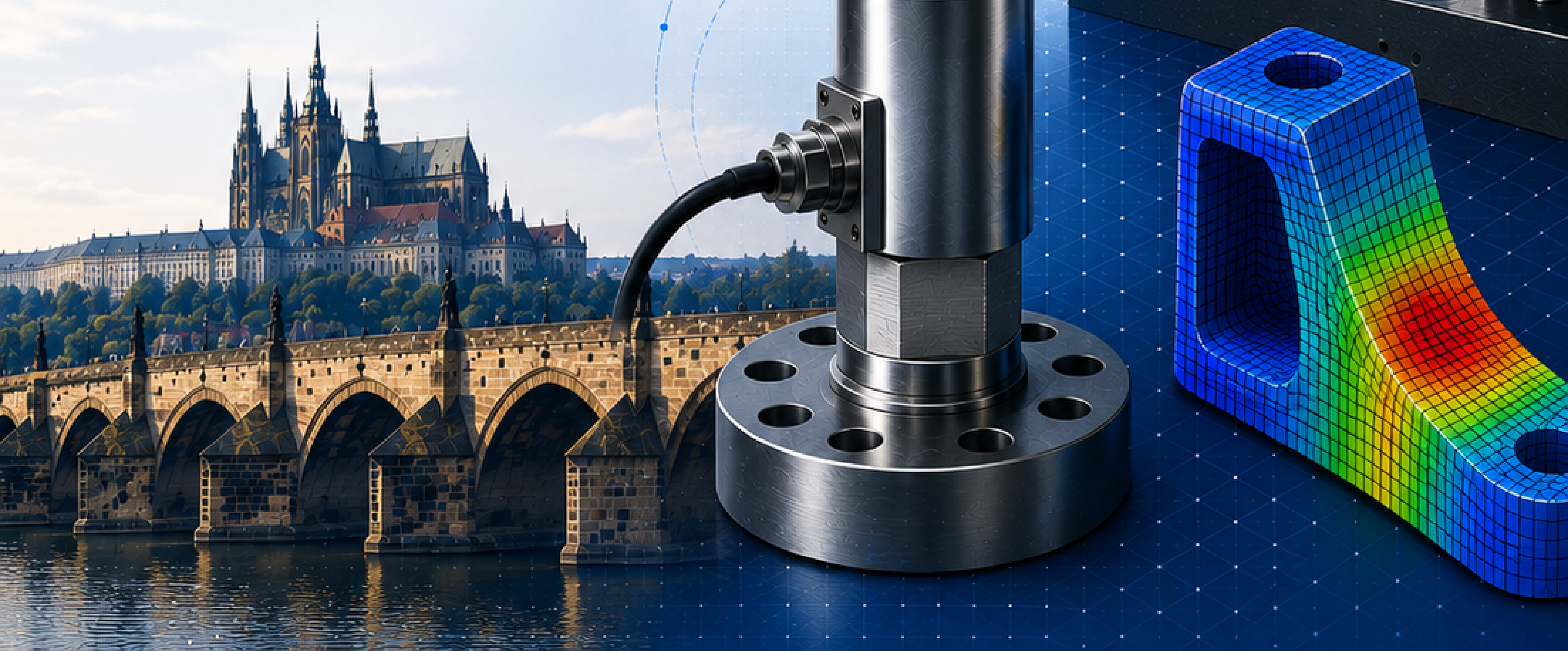

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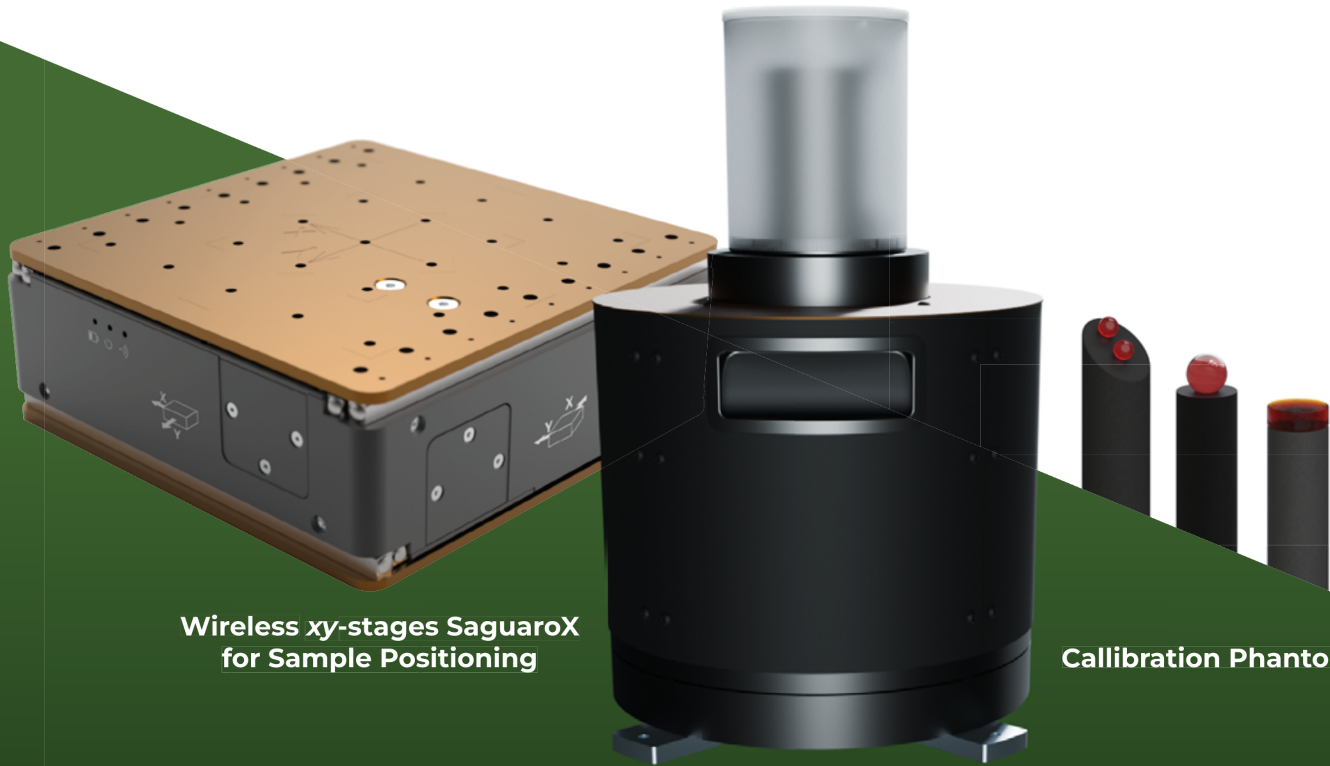

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Book of Abstracts

IMEKO TC15 Collegium 2026

IMEKO TC15 Collegium 2026, June 10 - 12 2026
Institute of Theoretical and Applied Mechanics, v.v.i., Prague, Czech Republic

under auspices of:
International Measurement Confederation (IMEKO) as TC15 event

Editors: Daniel Kytýř, Petr Zlámal and Andrija Zaplatić

Book of Abstract
IMEKO TC15 Collegium 2026

Editors: Daniel Kytýř, Petr Zlámal and Andrija Zaplatić

Publisher:
Czech Academy of Sciences, Institute of Theoretical and Applied Mechanics
Prosecká 809/76
190 00 Prague 9

30 pages

ISBN: 978-80-53071-01-7 (online)
DOI: 10.21495/01-7
Cover image: AI-generated illustration

IMEKO TC15 Collegium 2026

IMEKO TC15 Collegium 2026 is a focused meeting bringing together researchers working on advanced experimental methods and numerical simulations for material characterisation, damage analysis, and structural health monitoring, including applications under extreme loading conditions. The meeting provides a forum to share recent results, exchange ideas, and discuss current challenges in both experimental and computational approaches. Emphasis is placed on open discussion and interaction, as well as on identifying opportunities for future collaborative research and joint project proposals among both established and emerging collaborators.

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Daniel Kytýř, Zvonimir Tomičević, Nejc Novak, Petr Miarka, Giangiacomo Minak, Tomáš Doktor

Contents

From clay to carbon-efficient design via additive manufacturing of sustainable refractories

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Abstract

Recycling and upcycling materials are essential strategies for advancing sustainable manufacturing practices and supporting the transition to a low-carbon economy within the refractory sector. These approaches aim to reduce reliance on virgin raw materials, minimize waste generation, and decrease the carbon emissions associated with refractory product manufacturing. The implementation of additive manufacturing technologies constitutes a major technological advancement, with principal applications in industrial design, architecture, and the arts. Incorporating recycled materials into additive manufacturing offers a technically robust approach to producing sustainable, carbon-efficient refractory products.

Subsequently, recycled materials were combined with traditional clay to create a matrix that achieved the targeted rheological properties. The resulting mixtures were analyzed for particle packing density, and rheological characteristics to assess their suitability for direct ink writing, a standard extrusion-based 3D printing technique. In addition to the extrusion-based process, the established vat photopolymerization technique, specifically digital light processing, was utilized to fabricate components with high dimensional accuracy for industrial applications. Furthermore, a novel hybrid approach combining vat photopolymerization and extrusion-based processes was implemented.

The printed and subsequently sintered specimens were examined using a combination of complementary characterization techniques, including optical microscopy, scanning electron microscopy, digital image analysis, mercury intrusion porosimetry, and micro-computed tomography. These methods provided statistically robust information on microstructural development and the three-dimensional distribution and characteristics of porosity.

Acknowledgment

This paper was created as part of project No. CZ.02.01.01/00/22_008/0004631 Materials and technologies for sustainable development within the Jan Amos Komensky Operational Program financed by the European Union and from the state budget of the Czech Republic

Katherine Readout: A Versatile Measurement Hub for Imaging and Materials Research

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Abstract

The Katherine readout device series represents a widely used platform for Timepix-class pixel detectors of ionizing radiation. It currently supports Timepix2, Timepix3, and more recently Timepix4 detector. The platform evolved from the first generation Katherine readout for Timepix3 (introduced in 2016), utilizing a Gigabit Ethernet interface with functionalities such as hardware pixel decoding, extended triggering, and detection of corrupted columns. This development marked a significant step beyond earlier readout systems that primarily served as protocol translators [1].

Increasing demands of multi-layer detector systems and higher data rates led to the development of Generation 2. This version supports up to eight detector layers, incorporates a USB 3.0 interface (up to 60 MHit/s), and features upgraded bias voltage sources (±1 kV), enabling applications such as X-ray imaging, coincidence measurements, and time-of-flight techniques [2].

For specialized applications, particularly particle tracking in large-scale experiments such as ATLAS and LHCb at CERN, dedicated device variants were developed, enabling operation in harsh environments (high radiation and magnetic fields) and over extended distances between sensors and readout electronics [3].

With the advent of Timepix4, a new design philosophy based on modern SoC FPGA devices was introduced, enabling integration of advanced functionalities directly into hardware. The Katherine platform adopts a modular approach, allowing rapid adaptation to different detector types and experimental setups.

In its current implementation, the platform provides Gigabit Ethernet and PCIe Gen3 x4 interfaces, corresponding to data rates of approximately 10 MHit/s and up to 350 MHit/s, respectively. Beyond detector readout, it is designed as a measurement hub with advanced triggering capabilities and an instrumentation connector enabling control of laboratory equipment (e.g. stepper motors, Peltier elements) via standard interfaces (UART, SPI, I2C, CAN, RS-485) [4].

Based on these functionalities, the Katherine platform shows strong potential for applications in advanced materials research and experimental studies. Rather than a fixed-purpose device, it represents a flexible platform that can be rapidly customized, with future support of Medipix4 expected to extend capabilities toward high frame-rate imaging.

Acknowledgment

This research was supported by the Technology Agency of the Czech Republic under grant No. TN02000012 and by the project SGS-2024-005: Modern methods of solution, design and application of electronic and communication systems.

References

[1] P. Burian et al 2017 JINST 12 C11001

[2] P. Burian et al 2025 JINST 20 C06077

[3] P. Burian et al 2018 JINST 13 C11024

[4] O. Růžička et al 2025 JINST 20 C06074

Dynamic and Quasi-Static Characterization and Cowper–Symonds Material Model Calibration of SLA Printed Resins

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Abstract

Photopolymer resins produced by stereolithography (SLA) 3D printing are increasingly utilized for fabrication of lightweight structures, lattice metamaterials, and components intended for deformation energy mitigation applications [1]. However, reliable numerical simulations of such structures subjected to dynamic loading require accurate constitutive models capable of describing strain-rate dependent material behavior. Despite the growing use of SLA printed polymers, experimental data suitable for calibration of dynamic constitutive models are still limited, particularly for commercially available engineering resins.

The presented study is focused on experimental characterization and constitutive model calibration of two SLA printing materials (i) Phrozen High-Resolution RPG Resin and (ii) Phrozen Standard Aqua Resin. Bulk specimens produced from both materials were prepared by SLA and subjected to quasi-static and high-strain rate loading. Quasi-static experiments were performed using a standard uniaxial loading device, while dynamic compression experiments were conducted using a split Hopkinson pressure bar (SHPB) apparatus. The SHPB instrumentation enabled the evaluation of stress-strain response at elevated strain rates.

Based on the experimentally obtained stress-strain curves, strain-rate sensitivity of both investigated resins was analyzed. Yield stress values corresponding to different strain rates were evaluated and subsequently used for calibration of Cowper–Symonds constitutive model parameters [2]. The calibrated material models are intended for implementation into LS-DYNA simulations employing the piecewise linear elastoplastic material models. The resulting constitutive descriptions will be used for future numerical investigations of dynamically loaded SLA printed lattice structures and metamaterials. The presented approach provides experimentally validated material data for reliable simulation of strain-rate dependent behavior of SLA printed resins.

Acknowledgment

The research was supported by the Czech Science Foundation in project no. 25-18209S. The work was carried out within the framework of the Strategy AV21 programme AI: Artificial Intelligence for Science and Society.

References

[1] G. Rasiya et al., Materials Today: Proceedings, 47, 19 (2021), DOI: https://doi.org/10.1016/j.matpr.2021.05.181

[2] J.-Z. Zhi et al., 2013 International Conference on Quality, Reliability, Risk, Maintenance, and Safety Engineering (QR2MSE), 1193–1195 (2013), DOI: https://doi.org/10.1109/QR2MSE.2013.6625781

Asynchronous explicit–implicit time integration for efficient SHPB simulations with localized nonlinear dynamics

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Abstract

We present an asynchronous explicit–implicit time integration framework for partitioned elastodynamic problems with strongly heterogeneous temporal scales, motivated by simulations of Split Hopkinson Pressure Bar (SHPB) experiments. In such problems, the specimen often contains highly refined meshes, nonlinear constitutive behavior, and viscoelastic or rate-dependent material models [1], while the surrounding elastic bars exhibit comparatively simple dynamics that do not require equally small time steps. The proposed method enables each subdomain to advance using its own local integration scheme and time increment, combining explicit integration in regions with fast nonlinear response and implicit integration in slowly varying parts of the model. Subdomains are coupled through localized Lagrange multipliers acting on accelerations within a mortar-type framework [2, 3]. Numerical studies demonstrate that the method preserves good accuracy while substantially reducing computational cost by avoiding globally restrictive time steps. The approach is particularly advantageous for SHPB simulations used in inverse identification and automatic optimization of material parameters, where repeated evaluations of computationally demanding specimen models dominate the overall cost. The presented framework therefore offers an efficient strategy for large-scale parametric studies and coupled optimization workflows involving complex rate-dependent materials.

Acknowledgment

The authors acknowledge funding by the Czech Science Foundation in project no. 25-18209S. R.D. acknowledge also institutional support RVO:61388998. Computational resources were provided by the e-INFRA CZ project (ID:90254), supported by the Ministry of Education, Youth and Sports of the Czech Republic.

References

[1] T. Fíla et al., Int. Journal of Impact Eng., 148, 103767 (2021), DOI: https://doi.org/10.1016/j.ijimpeng.2020.103767

[2] R. Dvořák and J. González, Comp. M. in App. Mech. and Eng., 432, 117336 (2024), DOI: https://doi.org/10.1016/j.cma.2024.117336

[3] A. Popp et al., Comp. M. in App. Mech. and Eng., 264, 67-80 (2013), DOI: https://doi.org/10.1016/j.cma.2013.05.008

Failure of Materials and Architected Structures at Intermediate and High Strain Rates: Experimental Techniques, Instrumentation and X-ray Imaging

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Abstract

Modern engineering materials are increasingly employed in applications involving dynamic loading conditions spanning intermediate and high strain-rate regimes. Understanding failure processes under such conditions is essential for the reliable design of lightweight and energy-absorbing systems. This challenge is particularly relevant for architected structures, metamaterials, graded materials, and sandwich systems, whose response is governed not only by the constitutive behavior of the base material but also by their complex internal architecture. At intermediate strain rates, the onset of inertia effects, wave propagation, and strain-rate sensitivity can significantly influence failure mechanisms, while at higher strain rates these effects become more pronounced and may be accompanied by adiabatic heating and damage localization. Experimental investigation is often challenging because the governing mechanisms originate within the material interior and remain inaccessible to conventional surface-based diagnostics.

This contribution presents experimental techniques recently developed at DynLab, Faculty of Transportation Sciences, Czech Technical University in Prague, for investigating failure processes in materials and architected structures subjected to dynamic loading. The methodologies combine controlled mechanical testing with high-speed X-ray imaging, enabling direct observation of internal deformation and damage evolution. For the intermediate strain-rate regime, the developed Linear Motor Impact Testing Actuator (LIMA) is introduced. The dual-linear-motor platform enables highly controlled tensile, compressive, bending, and penetration experiments while maintaining well-defined boundary conditions and compatibility with high-speed optical imaging, flash X-ray radiography, and in-situ X-ray computed tomography. For high strain-rate investigations, Hopkinson-bar-based techniques combined with flash X-ray imaging are presented, enabling characterization of rapid failure phenomena together with observation of internal deformation, collapse mechanisms, and damage localization. Finally, ongoing developments aimed at extending the experimental capabilities are discussed, including predictive-control approaches for improved loading accuracy, high-speed X-ray computed tomography enabled by synchronized rotary stages integrated into the LIMA platform, and enhanced X-ray imaging using direct-conversion CdTe photon-counting detectors. Together, these developments provide a pathway toward comprehensive characterization of dynamic failure processes across a broad range of loading rates.

Acknowledgment

This research was funded by the Czech Science Foundation, Czech Republic (project Junior Star No. 22-18033M). The support is gratefully acknowledged.

Integrated Numerical Simulation and Machine Learning Framework for Estimating the Fatigue Performance of High-Strength Steel under Extreme Loading Conditions

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Abstract

Under extreme load conditions, the material undergoes structural degradation, culminating in permanent deformation and catastrophic failure. Complex cyclic loading, along with a severe corrosive environment and intrinsic imperfections from laser-based additive manufacturing, induces defects that could act as crack initiation sites [1]. Estimating the durability of engineering materials exposed to extreme environments and complex cyclic loads remains challenging owing to the stochastic distribution of defects and nonlinear damage accumulation inherent to fatigue. This study presents the hybrid model to predict the durability of 18Ni-300 steel produced by laser powder bed fusion, subjected to a simulated marine environment. The detrimental effect of corrosion is accounted for through the stress concentration factor obtained by numerical analysis and the mass loss index, while the complex cyclic loading effect is accounted for through the Matake multiaxial criteria [2]. An error-driven hybrid SVR model (E-SVR) is employed to capture nonlinear variation in predicted fatigue life through Matake multiaxial criteria and experimental fatigue life. The developed model is validated through the coefficient of determination, root mean square error, and fatigue scatter (T). Furthermore, the internal structures and post-fatigue crack features were analyzed through quantitative fractography and tomography analysis to provide insights into crack initiation and propagation mechanisms. The result indicates that the developed hybrid numerical-semi-empirical machine-learning model effectively captured the nonlinear fatigue characteristics and effectively predicts the durability of LPBF 18Ni-300 steel under the coupled effect of aggressive environment and cyclic loading.

Acknowledgment

This research was supported by Opole University of Technology under the funding provided by the discipline of mechanical engineering.

References

[1] M. Morgantini et al., In Proceedings MATEC Web Conf. (2018), DOI: 10.1051/MATEC-CONF/201816503001

[2] B. Crossland et al., In Proceedings Int. Conf. on Fatigue of Metals, (1956), HAL Id: 04700578

Digital twin framework for structural health monitoring and safety assessment of ageing concrete gravity dams

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Abstract

Concrete gravity dams represent critical infrastructure whose long-term safety relies on continuous monitoring and reliable predictive modelling. Over decades of operation, the dams are continuously exposed to sustained hydrostatic pressure, seasonal thermal variations, time-dependent phenomena such as creep, and foundation movements, among others. Accurate assessment of their current condition and remaining resistance requires the integration of monitoring data with advanced physics-based numerical models.

This work presents a digital twin framework for structural health monitoring and failure risk assessment of ageing concrete gravity dams. The proposed approach combines field monitoring data with an advanced finite element model of dam-reservoir interaction [1]. Within the numerical framework, the dam is represented as a nonisothermal saturated porous medium and discretised using a fully coupled thermo–hydro–mechanical discrete beam lattice model based on a Voronoi tessellation, capable of capturing crack initiation and propagation within the dam body. The reservoir water is represented as an acoustic fluid and discretised using a mixed displacement–pressure finite element formulation. The selected finite element approximations for both domains ensure seamless coupling at the dam–reservoir interface [2]. The resulting numerical model of dam-reservoir interaction supports both the assessment of the current condition of the dam under operational loads, as well as the prediction of remaining resistance and failure mechanisms under extreme loading conditions [3].

The development and calibration of a digital twin for operational concrete gravity dams requires the systematic integration of monitoring data. Temperature measurements, reservoir levels, and displacement records provide the basis for identifying the key material parameters that govern the structural response. By minimizing the discrepancies between measured and simulated responses, the calibration procedure ensures that the digital twin reliably reflects the current condition of the ageing dam. Once calibrated, the digital twin serves to simulate the dam response under combined operational and extreme loads, enabling the assessment of remaining structural resistance.

The proposed framework contributes to dam safety management by providing a robust tool for continuous assessment of the current condition of the dam, parameter updating, and prediction of structural performance under extreme events. By coupling monitoring data with a physics-based numerical model capable of capturing failure mechanisms, this approach supports informed decision-making and risk mitigation strategies for ageing hydraulic infrastructure.

References

[1] E. Hadzalic and A. Ibrahimbegovic., Computation (2025), DOI: 10.3390/computation13050118

[2] E. Hadzalic et al., Coupled Syst. Mech. (2018), DOI: 10.12989/csm.2018.7.6.649

[3] E. Hadzalic et al., Comput. Struct. (2019), DOI: 10.1016/j.compstruc.2019.01.003

Peridynamics as a framework for fatigue crack growth prediction in metallic components

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Abstract

Fatigue crack growth is still most commonly analysed within classical continuum mechanics and fracture mechanics, where stresses and strains are defined through spatial derivatives of the displacement field. Since a crack is a displacement discontinuity, these differential descriptions lead to singular crack-tip fields and numerical crack-growth analysis therefore relies on additional fracture parameters, such as the stress intensity factor, together with crack-growth criteria and mesh adaptation. Peridynamics (PD) reformulates the continuum in nonlocal form, describing internal forces through interactions between material points over a finite horizon [1]. Because its governing equations are integral rather than differential, the presence of discontinuities does not invalidate the formulation. Crack growth can therefore be represented directly through progressive bond failure, without remeshing and without prescribing the crack path in advance. In this contribution, a bond-based PD model coupled with the kinetic theory of fracture (KTF) is presented for fatigue crack growth and remaining-life prediction in metallic components, building on previous calibration work based on crack-length-versus-cycles (a–N) data [2]. The focus is placed on homogeneous metallic specimens under cyclic loading, using representative compact tension and single-edge bending configurations to introduce the predictive workflow and to illustrate how the numerical response changes when calibrated parameters are transferred between geometries. The contribution is intended as a precise introduction to peridynamic fatigue analysis for the experimental mechanics community and as a basis for broader ongoing validation on more complex material systems.

Acknowledgment

The authors acknowledge the support of the Slovenian Research and Innovation Agency (ARIS) within programme P2-0137 and the bilateral collaboration between the University of Maribor and the University of Arizona.

References

[1] S. A. Silling, Journal of the Mechanics and Physics of Solids 48 (2000), DOI: 10.1016/S0022-5096(99)00029-0

[2] F. Jerenec et al., Engineering with Computers (2024), DOI: 10.1007/s00366-024-02097-6

Finite element modeling and X-ray imaging of auxetic lattices LPBF printed from metal alloys

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Abstract

The advances in methods of metal additive manufacturing, particularly laser powder bed fusion (LPBF) of powdered alloys, has significantly contributed to the development of lattices and sandwich panels for deformation energy mitigation. In particular, the excellent mechanical properties of base material used for production of such a cellular solid can be combined with specific geometry of the unit-cells to obtain, e.g., auxetic lattices typical for their negative Poisson's ratio (NPR) during deformation response with very high specific energy absorption performance.

In this work, we study the compressive deformation response of various auxetic lattices LPBF printed from aluminium or steel alloys under quasi-static loading and dynamic impact based on split Hopkinson pressure bar (SHPB) loading. In addition to experiments performed using in-house designed loading devices, finite element (FE) simulations of both loading regimes are performed in ANSYS and LS-DYNA. Following previous studies concentrated on the influence of 3D printing imperfections and defects on both locan and global mechanical properties [1] and the problems of precise FE modeling, particularly in the case of numerical SHPB representations based on the full three-bar arrangement of the apparatus [2], we concentrate on the differences in numerical predicitons and the observed deformation response of the lattices.

For this reason, the X-ray computed microtomographical (XCT) imaging is used for volumetric investigation of the specimen geometry either in comparison of design against the actual produced specimens in case of the dynamic loading or as a full time-lapse 4D XCT scanning of the incrementally loaded lattices in the quasi-static regime. Here, digital volume correlation (DVC) is also used to establish displacement fields in the deforming lattices. In comparison of the numerical and experimental results, the differences in predicted and measured mechanical and geometrical characteristics are studied also using strain dependent Poisson's ratio and discussed on a comparison of parameters of the constitutive models or geometrical differences.

Acknowledgment

The authors acknowledge funding by the Czech Science Foundation in project no. 25-18209S. Computational resources were provided by the e-INFRA CZ project (ID:90254), supported by the Ministry of Education, Youth and Sports of the Czech Republic. The work was carried out within the framework of the Strategy AV21 programme AI: Artificial Intelligence for Science and Society.

References

[1] P. Magaro et al., Mater. Sci. Eng., A 863, 144526 (2023), DOI: 10.1016/j.msea.2022.144526

[2] Z. Song et al., Compos Struct 236, 111834 (2020), DOI: 10.1016/j.compstruct.2019.111834

Experimental investigation of polyurethane foam bonded brick masonry

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Abstract

The increasing demand for faster, cleaner, and more energy-efficient construction methods has accelerated the adoption of innovative bonding technologies in masonry. Among these, polyurethane (PU) foam adhesives have emerged as a promising alternative to traditional cement-based mortars. Applied as a thin bonding layer, PU adhesives enable rapid installation, reduced material consumption, and elimination of on-site wet-mix processes, contributing to improved construction efficiency. In addition, the low thermal conductivity of PU joints reduces thermal bridging within masonry walls, enhancing their overall energy performance [1]. Previous studies have also indicated improved ductility and energy dissipation capacity in PU-bonded masonry, suggesting potential advantages in seismic applications [2].

Despite these benefits, the structural applicability of PU foam joints is primarily governed by their bond performance with masonry substrates. Bond strength depends on both the mechanical properties of the adhesive and masonry units. Although several experimental studies have investigated the behavior of PU-bonded masonry systems, comprehensive data on the bond performance of PU joints in brick masonry remain limited.

This work presents an experimental investigation of the mechanical performance of PU foam joints in brick masonry. The experimental program included testing under two conditions: (i) curing in a controlled laboratory environment prior to testing, and (ii) exposure to natural weather conditions prior to testing to evaluate environmental effects. Direct tensile and shear bond tests were conducted to quantify bond strength, stiffness, and overall mechanical response of the PU-bonded specimens.

The results provide insight into the tensile and shear bond behavior of PU foam joints in brick masonry assemblies. Particular emphasis is placed on evaluating the influence of environmental exposure on strength and stiffness degradation. The comparison between laboratory-cured and weather-exposed specimens enables assessment of durability-related performance changes and their implications for structural application.

The findings contribute to the ongoing evaluation of PU foam as a structural bonding system for masonry construction. The results support the development of reliable design parameters and provide a reference dataset for future analytical and numerical modeling of PU-bonded brick masonry. Overall, this research advances the understanding of PU-bonded masonry systems and their potential application in load-bearing, and energy-efficient wall structures.

Acknowledgment

This work has been supported by the Croatian Science Foundation under project Resilient Engineering of Ductile Bonded Masonry: Understanding Dynamic Behavior and Seismic Response Across Scales (Resi-BOND, HRZZ-UIP-2025-02-2749).

References

[1] G.I. Grinfeld et al., Advanced Materials Research. (2014), DOI: 10.4028/www.scientific.net/AMR.941-944.786

[2] D. Foti et al., Advances in Materials Science and Engineering. (2018), DOI: 10.1155/2018/8640351

X-ray Computed Tomography for Non-Destructive Evaluation of Steel Wire Ropes: Influence of Acquisition Parameters on Damage Detectability

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Abstract

Steel wire ropes are critical load-bearing components in engineering infrastructure, where hidden internal damage, broken wires, corrosion, or local loss of metallic area may significantly affect structural safety and the remaining service life of constructions. Their multi-strand architecture makes damage assessment particularly challenging, as defects may initiate or propagate inside the rope structure and remain inaccessible to direct visual inspection. Conventional field inspection methods, particularly visual inspection and electromagnetic techniques such as Eddy current testing, are widely used for the operational assessment of wire ropes; however, their sensitivity to complex internal damage states and local defects in geometrically constrained regions remains limited [1].

X-ray computed tomography (XCT) offers a complementary non-destructive evaluation approach by enabling three-dimensional visualization of the internal architecture of steel wire ropes, including features hidden within individual strands and between wires [2]. In this study, intact and damaged wire rope samples, together with an individual fractured steel wire, are examined using different XCT systems and acquisition configurations. The main objective is to assess how instrumentation and acquisition parameters affect the detectability of wire fractures and fine-scale internal damage features, as well as the resulting spatial resolution, image quality in the reconstructed 3D image, and suitability of the data for subsequent quantitative analysis.

The comparison provides an initial assessment of the practical applicability and limitations of laboratory XCT inspection of steel wire ropes, particularly with respect to the smallest detectable damage features, the achievable data quality, and the acquisition time required for reliable analysis. The study also focuses on identifying acquisition settings that provide sufficient contrast and spatial resolution for damage localization and segmentation without impractically long scanning times. This is essential to extend the XCT inspection from short laboratory specimens to structurally relevant rope lengths. The obtained datasets provide a basis for the development of XCT-based diagnostic workflows aimed at quantitative damage characterization and future assessment of residual load-bearing capacity and remaining service life.

Acknowledgment

The research was co-funded by the European Union under the INODIN project, no. CZ.02.01.01/00/23_020/0008487.

References

[1] Zhou P. et al., Applied Sciences (2019), DOI: 10.3390/app9132771

[2] Huang H. et al., Russ. J. Nondestruct. Test. (2026), DOI: 10.1134/S1061830925604647

Multi-modal and multiscale dynamic imaging for a comprehensive material characterization

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Abstract

Hard X-ray imaging techniques can be applied in many fields, from biomedicine to materials science, from archaeology to Earth science studies, both using laboratory- and synchrotron-based X-ray sources. Research, as well as industrial applications, can benefit from the non-destructive character of these techniques allowing the investigation of the external and internal features of an object in the three-dimensional (3D) domain working in static and dynamic (4D = 3D + time) conditions. Recent advances in the complementary use of X-ray and neutron-based 3D imaging techniques, coupled with computational modeling, can offer a deeper understanding in the characterization of materials relevant for the building [1] and energy sectors [2, 3].

As an example, the textural and geometrical properties of pore networks, including pore size distribution, shape, connectivity, and tortuosity, play a crucial role in the storage and migration of geofluids within porous reservoir rocks. Advanced X-ray and neutron imaging techniques, coupled with computational fluid dynamics, can offer a deeper understanding of how the pore network properties influence fluid transport and the impact of macrofractures on storage and transport at the microscale. A similar approach can be applied to building materials to investigate hydration processes and the impact on durability and mechanical performances of these materials.

The main advantages and limitations of these techniques will be illustrated together with advanced methods of image processing and analysis. Several case studies will be used to understand the potential of these modern 3D/4D methodologies when coupled to numerical simulations for a comprehensive material characterization.

Acknowledgment

The author acknowledges the Slovenian node of E-RIHS (I0-E012) and financial support from the Slovenian Research and Innovation Agency (core funding P2-0273, Infrastructure I0-0032, and equipment co-financed under Packages 21 and 23).

References

[1] I. Adámkováet al., Build. Eng. (2024), DOI: 10.1016/j.jobe.2024.109089

[2] M. Zambrano et al., Front. Earth Sci. (2019), DOI: 10.3389/feart.2019.00329

[3] F. Rossi et al., ChemElectroChem. (2022), DOI: 10.1002/celc.202101537

Influence of Water to Cement Ratio on Fatigue Resistance of Concrete

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Abstract

Fatigue crack propagation in building materials often receives attention only after catastrophic structural failure. This contribution presents systematic experimental results on the fatigue damage mechanisms of high-performance concrete (HPC) produced with different water-to-cement (w/c) ratios. The experimental investigation examines fatigue damage phenomena across multiple scales and establishes links between microstructural features and the macro-scale (specimen-level) response. The observed differences in crack propagation have important implications for structural design.

Less is More: Few-Shot Learning in 3D Super Resolution using Synthetic CT Images

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Abstract

Computed tomography (CT) is widely used in non-destructive testing, archaeology and medical imaging, but often suffers from a limited field of view (FOV) and a trade-off between radiation dose and image quality. Super resolution (SR) methods can mitigate these limitations by enhancing the spatial resolution of the scan. However, supervised SR approaches typically require large amounts of paired low-resolution (LR) and high-resolution (HR) data, which are expensive and difficult to acquire in practice.

To address this restriction, we investigate how SR models trained on synthetic data can be adapted to real CT data with minimal supervision. In particular, we study how many real LR–HR pairs are required to achieve strong performance when fine-tuning models trained on synthetic data. In contrast to existing approaches for degradation modeling [1], we evaluate performances of degradation and SR networks with real LR acquisition. The study is divided into three stages: First, a shallow degradation model is trained and improved in order to synthesize realistic LR samples based on our previous work [2]. Next, a 3D-based SR network is trained with purely synthetic data. Lastly, the SR model is fine-tuned using a reduced set of real data pairs to examine the trade-off in prediction quality.

We train and evaluate our method on isolated sets of micro-CT scans of closed-cell aluminum foam specimens. For quantitative comparison, the learned perceptual image patch similarity (LPIPS) [3] metric is used. A bicubic interpolation baseline achieves an average value of 0.8689, while the model trained purely on synthetic data significantly improves performance to 0.3463. Fine-tuning the SR model on one sample and 16 samples results in a marginal prediction improvement from 0.2918 to 0.2867. This implies diminishing returns beyond a single sample in fine-tuning.

Overall, our findings demonstrate that combining synthetic training with limited real-data fine-tuning reduces the need for real LR–HR pairs while preserving image quality in CT.

Acknowledgment

This work is funded by the IBW/EFRE- & JTF 2021-2027 project 'HyperMAT' and by the government of Upper Austria within the project 'VISION' (grant no. 921357).

References

[1] Liu, Xiaobao, et al. Super-resolution reconstruction of ct images based on multi-scale information fused generative adversarial networks. Annals of Biomedical Engineering. 2024. 52. Jg., Nr. 1, S. 57-70. DOI: 10.1007/s10439-023-03412-w

[2] Nepelius, Lukas, et al. Impact of Synthetic and Real CT Training Datasets for Deep Learning Super Resolution Models. In: Proceedings of the e-Journal of Nondestructive Testing Vol. 31(3). 2026. DOI: 10.58286/32559

[3] Zhang, Richard, et al. The unreasonable effectiveness of deep features as a perceptual metric. In: Proceedings of the IEEE conference on computer vision and pattern recognition. 2018. S. 586-595. DOI: 10.48550/arXiv.1801.03924

Experimental characterisation and computational design of architected cellular metamaterials

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Abstract

Architected cellular metamaterials offer exceptional potential for energy absorption, stiffness tailoring, and multifunctional mechanical response, but their development still requires reliable frameworks that connect experimental characterisation with computationally efficient predictive models [1]. This contribution presents an experimentally validated framework for the design and analysis of cellular metamaterials subjected to quasi-static and impact loading. The approach combines homogenised constitutive modelling for closed-cell architectures with discrete finite-element representations based on beam, shell, and solid elements for strut-based and triply periodic minimal surface (TPMS) lattices, enabling efficient treatment of different deformation mechanisms and length scales.

The numerical models are calibrated and validated against mechanical tests by comparing stress-strain response, collapse modes, and deformation patterns over a broad range of loading rates [2]. This validation then supports design-oriented studies, including topology optimisation of auxetic concepts with tailored negative Poisson's ratio and the development of hybrid TPMS lattices with spatially varied unit-cell topology. The simulations show that hybridisation and local geometric control can be used to tune stiffness, energy-absorption capacity, and progressive collapse behaviour while maintaining good agreement with experimentally observed responses.

The main contribution of the presentation is a unified methodology that links material characterisation, model selection, numerical validation, and structural optimisation within a single workflow for additively manufactured metamaterials. Its novelty lies in combining reduced-order homogenised models and high-fidelity discrete models with experimental verification to support the systematic design of multifunctional lattice architectures for extreme mechanical loading [3].

Acknowledgment

The authors acknowledge the financial support of the Slovenian Research and Innovation Agency for the national research programme, funding No. P2-0063 and basic research project No. J2-60049.

References

[1] O. Al-Ketan et al., Addit. Manuf. (2018), DOI: 10.1016/j.addma.2017.12.006.

[2] N. Novak et al., Thin-Walled Struct. (2023), DOI: 10.1016/j.tws.2023.111109.

[3] N. Novak et al., Compos. Struct. (2022), DOI: 10.1016/j.compstruct.2022.116174.

Spiral X-ray Computed Tomography of Long Wooden Samples: Influence of Pitch and Geometric Calibration on Reconstruction Quality

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Abstract

X-ray computed tomography (XCT) is widely used for three-dimensional characterization of material microstructure. In wood science, XCT increasingly serves as a tool for quantitative analysis of annual rings, porosity, and other structural features requiring high reconstruction fidelity and geometrical consistency. Spiral XCT enables scanning of samples exceeding the detector field of view in height by combining continuous rotational motion with synchronized vertical translation during acquisition [1].

This work investigates the sensitivity of spiral XCT reconstruction quality to mechanical alignment, motion synchronization, and geometric calibration. For long wooden samples, reconstruction quality depends on the agreement between the assumed spiral trajectory and the actual coupled rotational and vertical motion during acquisition. Misalignment of the rotation axis with respect to the source–detector geometry, together with inaccuracies in vertical translation or magnification scaling, can introduce artifacts, blurring, and loss of structural fidelity.

The effect of spiral pitch, i.e. the vertical displacement of the sample per full rotation, was evaluated by varying the axial advance during acquisition. Larger pitch values reduced reconstruction quality, mainly due to lower axial sampling density and increased interpolation sensitivity during reconstruction. The study also demonstrates the importance of accurate magnification scaling in cone-beam spiral XCT, as it links the physical sample motion to the reconstruction coordinate system. Incorrect scaling produces a mismatch between the vertical translation during acquisition and the reconstructed voxel geometry, resulting in geometric distortions, layer misalignment, and degradation of image quality. These results show that reliable spiral XCT reconstruction of long wooden samples requires accurate geometric calibration together with precise control of the coupled rotational and vertical motion.

Acknowledgment

This research was supported by Czech Science Foundation (Project No. 25-18144S). D. Kytyr acknowledges the support from OP JAK (Project INODIN CZ.02.01.01/00/23_020/0008487).

References

[1] Brink J.A. et al., Radiographics (1994), DOI: 10.1148/radiographics.14.4.7938775

Numerical Investigation of Low-Cycle Fatigue in TPMS Metamaterials

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Abstract

Triply periodic minimal surface (TPMS) metamaterials are increasingly considered for lightweight engineering applications because they combine continuous cellular geometry with favourable mechanical performance, including high stiffness-to-weight ratio, damping capability, and energy absorption. Despite these advantages, their fatigue response under large cyclic deformation is still not fully understood. This study numerically investigates the low-cycle fatigue behaviour of three sheet-based TPMS topologies: Gyroid, Diamond, and Primitive. The main objective was to assess how cell geometry and imposed strain amplitude affect fatigue crack initiation. Finite element models were generated using $2 \times 2 \times 4$ unit-cell domains, while symmetry boundary conditions were applied to represent the response of an equivalent $4 \times 4 \times 4$ structure with reduced computational cost. Aluminium alloy 5083-H111 was used as the base material and described by an isotropic elastoplastic model with kinematic hardening to capture cyclic plastic deformation. Because the analysed loading conditions involved relatively large strain amplitudes, fatigue life estimation was based on the strain-life approach, which is suitable for low-cycle fatigue problems. All simulations were performed under fully reversed strain-controlled cyclic loading and included both material and geometric nonlinearities. The results indicate that fatigue crack initiation is strongly affected by the selected TPMS topology. Differences in surface curvature, stress concentration, and load transfer mechanisms led to distinct fatigue responses among the investigated geometries. The findings demonstrate that topology selection is a critical factor in the fatigue performance of sheet-based TPMS metamaterials. This work provides useful insight for the design and optimisation of lightweight cellular structures intended for applications where durability, cyclic loading resistance, and energy absorption are important.

References

[1] O. Al-Ketan et al., Adv. Eng. Mater. (2019), DOI: 10.1002/adem.201900524

[2] W. H. Meeks III, The Theory of Triply Periodic Minimal Surfaces (1990)

Experimental characterisation of cellular meta materials for application as trauma pad for multi-hit capabilities

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Abstract

A typical body armour consists of a layered structure, which includes a hard shell that can absorb the kinetic energy through deformation and a soft energy absorber known as trauma pad that can capture the deformation of the hard shell. In this work, triply periodic minimal surface (TPMS) structures are investigated for their application as trauma pads in body armour. Energy absorbers such as in automotive crash boxes are conventionally designed for a single use application. However, body armours which can be loaded multiple times during an operation, should exhibit multi-hit capabilities. Therefore, the TPMS structures are not only investigated for their energy absorption capabilities, but also for their elastic recovery.

In the presented work, the investigations were conducted on a scaled down version of the trauma pad, without the use of the front shell. Different TPMS structures were first compared experimentally for their energy absorption capabilities. Elastomeric material was used to additively manufacture these structures. The material parameters for the elastomer were determined using tensile and compression tests. A numerical model using finite element method (FEM) was implemented to fit a viscoelastic material model to the tested elastomer. The FEM model was validated by comparing the experimental results of TPMS structures to the numerical results.

In order to investigate the multi-hit capabilities, these structures were loaded experimentally under cyclic compression loads and the residual deformation after the consequent cycles were analysed. Moreover, the effect of relaxation times between the load cycles were also investigated, by resting the samples in a protected environment between the loading cycles. The tests were conducted in the quasi-static and in the dynamic loading range. Further cyclic loading were conducted numerically with the validated simulation model. The results shows that in the subsequent loading cycles, the energy absorption capabilities reduces, however, it tends to an equilibrium state after a certain number of loading cycles has been applied.

Full-field volumetric characterization of a tetrachiral lattice structure under compression

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Abstract

Modern engineering increasingly relies on lightweight materials that combine high strength, energy absorption capability, and adaptability to application-specific requirements. Additive manufacturing (AM) enables the fabrication of lattice structures (LS); architected materials composed of periodically repeated geometric patterns that achieve exceptional strength-to-weight ratios. Such structures show considerable potential in aerospace, automotive safety systems, and biomedical engineering applications. However, their mechanical behaviour remains difficult to predict because real additively manufactured structures exhibit complex multiscale deformation mechanisms that influence their structural response.

Most studies on AM LSs rely on surface-based measurements or numerical simulations using idealized geometries, which do not capture the true bulk behaviour of real structures. Digital Volume Correlation (DVC) combined with in-situ X-ray computed tomography (XCT) has become a well-established method for full-field volumetric characterization of internal deformation mechanisms [1]. However, only a limited number of studies have applied this approach to small-scale lattice structures, with only a few experimental–numerical investigations conducted on metallic specimens [2, 3]. Furthermore, applying DVC to LSs remains challenging due to the high spatial resolution required to resolve fine features and the low gray-level (GL) gradients within the material bulk.

Within this study, volumetric characterization of the compressive behaviour of a 3D tetrachiral lattice structure was performed by combining 4D XCT and finite element (FE)-based DVC. The specimen was additively manufactured from Phrozen RPG resin using stereolithography (SLA) with a periodic architecture of $9 \times 9 \times 9$ unit cells. Mesh backtracking was implemented to account for manufacturing-induced geometric imperfections [3]. Due to the large deformations occurring during compression, the kinematic fields were registered using combined incremental and direct DVC calculations with Hencky regularization to mitigate the ill-posedness caused by the lack of GL contrast within the material bulk. The proposed methodology enabled accurate characterization of the complex deformation behaviour and provided an experimentally informed digital twin of the LS suitable for mechanical analysis and model validation.

Acknowledgment

This work was performed within the GENKON project funded by the European Union under the National Recovery and Resilience Plan (Grant No. NPOO.C3.2.R3-I1.04.0121). This work was also partially supported by the Czech Science Foundation (Project No. 25-18209S), the Strategy AV21 programme "AI: Artificial Intelligence for Science and Society".

References

[1] A. Vrgoč et al., Compos. Sci. Technol. (2023), DOI: 10.1016/j.compscitech.2023.109932

[2] P. Koudelka et al., Emerg. Mater. (2025), DOI: 10.1007/s42247-024-00973-x

[3] M. Valmalle et al., Mech. Mater. (2026), DOI: 10.1016/j.mechmat.2026.105602

Monitoring of crack propagation in anisotropic geomaterials during compressive strength testing using gas permeability measurements

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Abstract

Microstructure of pores in rocks and similar rock-like geomaterials includes size distribution, volume, shape, orientation and connectivity of pores and cracks and has a significant influence on many macroscopically observed and measured properties such as rock strength and its deformation and fracture behaviour. It also significantly influences fluid transport and storage capacity and co-determines rock resistance to weathering. Together with related rock permeability, it is therefore the decisive factor in assessing the suitability of rock host environment for demanding technical applications such as geological disposal of high-level radioactive waste or carbon sequestration in geological formations. It is obvious that rock permeability not only reflects physical and petrographical properties of the rock material itself, but also depends on the intensity of rock failure. The state of stress that leads to the closing of the pore system reduces rock permeability. Conversely, the rock damage processes induced by continued loading cause the origin and development of cracks, which often very significantly increases rock permeability. This close relationship between the permeability of a rock to fluids and the state of the stress, or rather the degree of failure of the rock material, means that the change in permeability coefficient values during loading can be used as a very sensitive indicator for monitoring crack initiation, propagation and growth within a test specimen. In addition to microstructure and mineralogical composition, another factor that significantly affects crack development is the anisotropy of the rock fabric. To observe changes in gas permeability during pressure loading, a rock with very well-marked textural anisotropy was used. Specifically, it was a high-grade metamorphosed stromatitic biotite migmatite, taken on the level 22 of the former Rožná I uranium mine. This site for sampling the tested rocks was also chosen because the generic Bukov Underground Research Facility, which plays an important role in terms of the overall research and development of deep geological repository of high-level radioactive waste in the Czech Republic, is located nearby. The permeability measurement equipment consists of a KTK 100 triaxial chamber adapted for the passage of gas. The ZWICK 1494 mechanical compression testing machine was used as a source of axial stress. The measurements were carried out on cylindrical test specimens with a diameter of 48 mm and a height of 96 mm. Test specimens were prepared in three directions with respect to the rock fabric anisotropy, namely perpendicular, parallel and oblique to the metamorphic foliation. It was found that rock anisotropy plays a very important role both on the course of gas permeability under loading and on the value of loading force at which the crack begins to propagate. While in the case of test specimens prepared perpendicular to foliation planes this moment occurs on average at 80 % of the maximum loading force, in samples parallel to foliation it occurs on average at 65 % of peak force. In the case of samples prepared oblique to foliation this moment depends on the value of the anisotropy angle between the foliation planes and loading direction and on the condition of anisotropy planes. Conducted research has shown that measuring changes in the gas permeability coefficient during loading can, to some extent, represent an alternative to other methods of studying the failure process in rocks, such as the acoustic emission technique.

Acknowledgment

This research was financially supported by the project CZ.02.01.01/00/23_020/0008487 (INODIN), co-funded by the European Union and project of the Czech Academy of Sciences – Strategy AV21, Research program: Dynamic Planet Earth (2023 - 2027).

Full-field characterization of shear-loaded woven composite

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Abstract

Composite materials are increasingly recognized as reliable substitutes for conventional engineering materials (e.g., metals). They are highly valued due to their excellent strength-to-weight ratio, which enables significant mass reduction of manufactured components. Moreover, the fiber architecture of composites can be tailored to meet the expected in-service loading conditions. However, their heterogeneous architecture makes predicting ultimate material failure particularly challenging. Consequently, extensive mechanical characterization under various loading regimes is essential. Mechanical testing devices such as the modified Arcan fixture (MAF) enable the application of different loading conditions to V-shaped butterfly specimens [1]. Owing to the complex geometry of Arcan samples, contactless measurement techniques are required to accurately characterize material behavior. Digital image correlation (DIC) [2] is among the most widely used optical methods due to its versatility and relative simplicity. Furthermore, the use of stereo DIC [3] allows for the measurement of out-of-plane displacements and complex deformations. Nevertheless, the aforementioned techniques are limited to surface kinematics. To capture bulk deformation, X-ray computed tomography (CT) combined with digital volume correlation (DVC) [2] can be employed. In this study, a composite specimen composed of woven glass fibers infused with vinyl ester resin was subjected to cyclic simple shear loading using the MAF. One surface of the specimen was monitored using a single digital camera, while the opposite surface was observed with a stereo optical system. Between loading cycles, ex-situ CT scanning was performed. The results revealed higher strain values on the surface monitored using 2D DIC compared to the opposite side. The DVC measurements of bulk kinematics in the unloaded state were consistent with the surface-based observations.

Acknowledgment

This work was performed within the GENKON project supported by the European Union and National Recovery and Resilience Plan Project (NPOO.C3.2.R3-I1.04.0121)

References

[1] A. Zaplatić et al., Exp. Mech. (2022), DOI: 10.1007/s11340-021-00762-1

[2] A. Vrgoč et al., COMPA. (2022), DOI: 10.1016/j.compositesa.2021.106576

[3] X. Chang et al., MSSP (2024), DOI: 10.1016/j.ymssp.2023.111057

Stress-Wave Propagation Across Material Interfaces in LPBF Multimaterial Metallic Specimens

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Abstract

Additive manufacturing of metallic components enables the fabrication of geometrically complex parts with locally tailored material properties. In particular, multimaterial metal printing offers the possibility of combining materials with different mechanical, thermal, or functional properties within a single component [1]. During stress-wave propagation in heterogeneous structures, incident waves are partially reflected and transmitted at interfaces between materials with different acoustic impedances. Therefore, understanding stress-wave propagation across such interfaces is essential for designing interface geometries and controlling wave propagation through structural modifications.

In this study, cylindrical multimaterial samples were prepared using the Laser Powder Bed Fusion technique [2]. The samples were manufactured from CuCr1Zr alloy and maraging steel 13Ni400 powders, with a nominal diameter of $20\,\mathrm{mm}$ and a length of $60\,\mathrm{mm}$. After printing, the samples were machined to achieve the final specimen geometry and required surface quality. The multimaterial build was carried out sequentially: first, one material was deposited, then the material interface was formed, and subsequently, the second material was printed. Each sample contained one material interface oriented perpendicular to the direction of stress-wave propagation, dividing the specimen into two equal parts. An in-house SHPB/OHPB apparatus, modified into an FDIHB configuration for direct impact testing, was used in the experimental campaign.

A short bar with a length of $5\,\mathrm{mm}$, made of either CuCr1Zr or 316L steel depending on the sample orientation during the test, was used as an impactor to generate a stress wave in the specimen. The impactor was mounted in a 3D-printed plastic carrier to ensure proper guidance inside the barrel. Each multimaterial sample was instrumented with two pairs of foil strain gauges, with one pair mounted on each material component, arranged in a quarter-bridge configuration. The strain gauges in each pair were mounted at the same distance from the impact face of the sample and positioned on opposite sides, i.e., rotated by 180 degrees with respect to each other. This redundant strain-gauge arrangement was used to determine whether the impact was properly aligned with the sample face.

The transmission bar, made of either CuCr1Zr or 316L steel, was instrumented with one pair of strain gauges positioned close to the bar face and one additional strain gauge located at the mid-length of the bar. The signals recorded from the strain gauges were post-processed and analyzed to evaluate the influence of the material interface on stress-wave propagation. Future work will focus on numerical simulations aimed at supporting the interpretation of the experimental results and providing a more detailed description of stress-wave reflection, transmission, and interaction at the material interface.

Acknowledgment

The research was supported by the Czech Science Foundation in project no. 24-11505S.

References

[1] A. Nazir et al., Mater. Des. 226 (2023) 111661, DOI: 10.1016/j.matdes.2023.111661

[2] O. Červinek et al., Virtual Phys. Prototyp. 19 (2024) 2396069, DOI: 10.1080/17452759.2024.2396069

Index