ICCSE2

2nd International Conference on Computations for Science and Engineering

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Book of Abstract

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Nicholas Fantuzzi

Michele Bacciocchi

Welcome Address

The abstracts collected in this book represent the proceedings of the conference ICCSE2 (2nd International Conference on Computations for Science and Engineering) , 30 August-2 September 2022. This book aims to help you to follow this Event in a timely and organized manner. Papers are selected by the organizing committee to be presented in mixed mode (virtual/phisical format). Such arrangement is due to the effects of the coronavirus COVID-19 pandemic. This event represents an opportunity for the scientifc community to discuss the latest advances on Methods and Applications regarding Science and Engineering Topics.

Conference chairs

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Contents

Abstracts

Applications- Aerospace Engineering

Modeling and Simulation of Automotive Crash-Box Using Natural Fiber Reinforced Composites

abst. 1023
"La Dolce Vita"
Thursday
September 1
11h45

Del Bianco, Giulia (giulia.delbianco@unicam.it), University of Camerino, Italy
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Energy absorption is a fundamental aspect in vehicles crash, especially in race competitions. Components like crash-box or bumpers must be properly designed to dissipate the propagated energy from the impact and guarantee driver's safety. Nowadays, carbon fiber reinforced epoxy resin composite is the most used material in structural components manufacturing. On the other side, enhance the use of green materials for crashworthiness applications is a current challenge, for both academic and industrial research, in order to pursue the environmental sustainability goals. Since composite materials reinforced with natural fibers show interesting properties from the energy damping point of view, this study focused on the substitution of laminae in carbon fibers with those woven with natural ones to obtain a hybrid composite component able to absorb the total amount of impact energy. The attention was focused on two kinds of natural fibers, flax and hemp respectively. The mechanical characterization of such thermoset composite laminates was joined by numerical modelling using finite element method, initially of simple geometries up to more complex structure such that of a truncated pyramidal crash-box. The design strategy of the entire component has been focused on finding the optimal stacking sequence for the laminate, in order to maximize the specific energy absorption (SEA). The numerical results were compared with experimental tests, showing a good ability of the model to reproduce the real crushing phenomenon, and highlighting the interesting performance of green composites from the crashworthiness point of view.

Development of a thermo-mechanical FE Model for an adaptive joining technology for pre-holed and pre-hole-free joints based on friction spinning

abst. 1063
"La Dolce Vita"
Thursday
September 1
12h00

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The design and production of modern lightweight structures require a multitude of mechanical joining processes. The joints place a wide spectrum of requirements on the joining processes. To fulfill these requirements, mechanical joining processes with joining elements are often used, which are usually designed for a single, specific application. This application-specific adaptation is accompanied by a high number of required variants of the auxiliary joining parts and thus a rigid process chain as well as high costs. One approach to overcoming these challenges is the development of an adaptive joining technology. With this technique, form-fit and force-fit connections can be produced employing

suitable adaptive joining elements, also known as Friction-Spun Joint Connectors (FSJC). The adaptive joining process consists of three sub-steps: the thermo-mechanical kinematic shaping of the adaptive joining element, the subsequent joining process, and the final separation of the adaptive joining element from the initial semi-finished bar material. This joining technique allows customized inline adaptation of the joining elements during the joining process. In the first process step, the geometric shape, mechanical properties, and microstructure of the adaptive joining elements are adjusted to meet specific requirements. Friction spinning is utilized for this purpose, which is a thermomechanical process in which the workpiece is heated locally through friction and plastic deformation. The application of temperature leads to increased formability of the adaptive joining element and thus also to a reduction in the process forces required for forming. Hence, the yield strength of the material is reduced without exceeding its melting point. Friction spinning is also used in the actual joining process. A distinction is made here between process strategies with pre-holed or non-pre-holed workpieces to be joined. The choice of process strategy depends on the material of the adaptive joining element used. During the joining process, the adaptive joining element is rotated and fed in the direction of the joint. As soon as the joining element comes into contact with the die, heat is generated as a result of friction. In combination with the axial feed stroke, the shape of the joint is generated. The joining process can also be adapted to the specific requirements in various ways, e.g., by the rotational speed, the feed rate, the geometric shape of the die and the workpiece as well as its mechanical properties. Comprehensive investigations are essential for the implementation of the adaptive joining technology. In conjunction with experimental analyses, numerical simulation of the process is a crucial tool for this purpose. The aim is to build a thermomechanical process model using the finite element method (FEM), which allows, among other things, the investigation of the material flow and the temperature distribution during the entire process. Numerical modeling of the adaptive joining process is confronted with numerous challenges. For example, initial investigations have shown that, due to the high degrees of deformation in conjunction with high rotational speeds of up to 12000 rpm, contact modeling and spatial discretization are significant subjects of investigation. Therefore, the FE program LS-DYNA (version R12.1) is used to compare different contact modeling approaches like the standard contact penalty formulation and the segment-based contact penalty formulation. This comparison is also carried out for different FEM-based approaches for spatial discretization, such as the pure Lagrangian approach and the Arbitrary Lagrangian Eulerian (ALE) approach. Furthermore, the impact of these modeling approaches on the thermo-mechanical coupling is highlighted.

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abst. 1082
"La Dolce Vita"
Thursday
September 1
12h15

Analysis and testing of an innovative fiber-reinforced composite laminate for advanced aeronautics: TERSA Project

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This project TERSA aims to develop a prototype of fixed-wing RPAS (Remotely Piloted Aerial System) with a max take-off weight of 25 kg with the following characteristics: electric hydrogen propulsion system for a high flight autonomy; Synthetic Aperture Radar (SAR) for surveillance missions even in hostile climatic conditions; SenseAvoid system, consisting of a dedicated miniSAR and a video camera, able to identify fixed or moving obstacles and manoeuvre to avoid them; V-TOL vertical take-off landing. A study was carried out aimed to define the fabric production processes and the subsequent vacuum bagging of prepreg composites based on carbon and epoxy resin. The goal was that: a new prepreg fabric with a very low weight: 65 grams per square meter with a percentage of epoxy resin of 47%; it is also identified an adequate compromise between the performance requirements and those of cost containment and pollution emissions, taking into account what will be the final application sector, i.e. the aeronautical one. Aknowledgements: The TERSA Project of CARBON DREAM SPA, University of Pisa and University of Bologna (DICAM) has won the tender "Accordi per l'innovazione" D.M. 24/05/2017, funded by Italian Ministry of Industry and Horizon 2020 of EU.

Folding behaviour of thin-walled tubular deployable composite boom for space applications: Experiments and numerical simulation

abst. 1084
"La Dolce Vita"
Wednesday
August 31
16h30

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Thin-walled tubular deployable composite boom (DCB) has attracted many attentions thanks to its lightweight, simple structure and high packaging efficiency. The experimental method and numerical simulation were employed in this paper to evaluate the folding behaviour of the DCB. Using T700/epoxy unidirectional reinforced prepreg as raw material, DCB specimens were prepared by the vacuum bag method. To complete the folding experiments of the DCB specimens, a coiling machine was designed and manufactured. Folding experiments of DCB specimens were carried out successfully and folding moment versus rotational displacement curves were measured. In addition, a Finite Element Model (FEM) was established to predict the folding behaviour of the DCB. Different failure criteria were considered in the numerical analysis, including the maximum stress criterion, Tsai [U+2010] Hill criterion and Tsai [U+2010] Wu criterion. Prediction results using the FEM were compared with experimental results, and the two were in good agreement. It is shown that the DCB can achieve the folding function without failure. The research results in this paper are of great significance to the practical engineering application of the lenticular DCB. Key words: Deployable composite boom; Vacuum bag method; Finite element model; Failure criterion.

abst. 1009
"La Dolce Vita"
Thursday
September 1
12h30

When structural mechanics meets computational biology: exploring large-scale functional protein motions via hdANM

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The biological activity of proteins is pivotal for a variety of physiological processes, as well as for the onset of deleterious malfunctions and diseases. Proteins generally perform their biological task in a highly dynamic fashion, their functional movements often being driven by their intrinsic flexibility. Since the late 1990s, it has been proposed that protein dynamics and flexibility can be efficiently and accurately investigated by modeling the protein structure via a bead-spring approach. The beads represent the protein atoms, while the springs simulate in a simplified way the interatomic interactions. Later on, it has been found out that proteins might behave as dynamic robots, whose motion can be described as the spatial translation and rotation of rigid blocks. For decades, these two different modeling techniques were employed quite independently to extract protein dynamics. The protein structure was modeled either as a flexible connection of spring or as an assembly of rigid blocks, even though it might be actually a mixture of the two. Proteins clearly exhibit some densely-packed regions, resembling rigid domains, and other less densely-packed portions of the structure, which might behave as flexible hinges. A large variety of protein conformational changes has been classified as hinge motions, with one or few flexible hinges accommodating the quasi-rigid motion of domains. Based on these considerations, here we present the hinge-domain Anisotropic Network Model (hdANM), a newly developed methodology that aims at extracting the large-scale motions of the protein, whose structure is modeled as a union of flexible hinges and rigid domains. The model takes the traditional bead-spring representation of the overall structure, while including the rigid-body equations of motions to the rigid domains. The hinge-domain partition of the structure can be evaluated based on a variety of numerical approaches. One of these is PACKMAN, a numerical method based on alpha shapes and Delaunay tessellation, which is able to predict the hinges of a generic protein structure only based on its geometry. Based on PACKMAN or other hinge prediction approaches, hdANM allows to evaluate the stiffness and mass matrix of the protein, by incorporating the rigid-body equations of domain motions into the traditional bead-spring model. The model then yields the complete set of eigenvalues and eigenvectors, which can be used to extract and study the dynamics of the structure. A non-linear extrapolation of the eigenvectors, following the domain rotations, is also included into the model in order to trace more realistically the large-scale non-linear motions of the protein. Eventually, these motions are informative of the biologically-relevant protein mechanisms and conformational changes. The model is more comprehensive than the previous ones, and it is based on a fewer number of degrees of freedom (DOFs), thus enhancing the computational efficiency. hdANM is now an open-source software, freely available, and hosted on a user-friendly website.

Applications- Civil and Environmental Engineering

Generation of finite element models from point clouds of historical structures through a user-friendly software

abst. 1014
"Amarcord"
Wednesday
August 31
16h30

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The acquisition of dense point clouds on existing and historical structures has become very common in the last decade. Still, the utilization of point clouds for the generation of finite element (FE) models is undervalued. In this contribution, a recent semi-automatic point cloud-to-numerical model procedure based on geometry description through slices is discussed. In particular, closed polygonal chains are distinguished on each slice and stacked vertically through voxels, which are then turned into 3D solid FEs. Such semi-automatic procedure is here implemented into a user-friendly software. Particularly, ad-hoc graphical tools are developed to support the user in case of non-comprehensive point clouds, i.e. when the point cloud does not fully collect all the inner and outer surfaces of the structure. Accordingly, the generation of FE models of historical buildings is guaranteed starting from point clouds of any level of completeness. Several real case study applications are discussed, and the reliability of the generated models in pursuing structural analyses is investigated.

Static analysis of axially FG circular helical springs via mixed FEM

abst. 1017
"Amarcord"
Thursday
September 1
14h30

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The aim of this study is to examine the static behavior of axially functionally graded circular helical springs via mixed finite element method. Helical springs are found in immense industrial applications like damping systems such as in automobiles, tanks and armored vehicles, railway bogie etc. due to their high energy absorption capacity. Composite materials have also widespread utilization in various engineering fields like civil, mechanical, marine, aeronautical and astronautical and defense industry due to their superior properties for instance high strength and stiffness-to-weight ratio or corrosion resistance, thermal, and sound insulation etc. Moreover, a structure produced using composite materials may increase both life cycle duration and decrease manufacturing cost. However, extreme variation in temperature or impact loading might lead cracks or delamination problems in classical composite materials (e.g. laminated composites). Thus, functionally graded materials (FGMs) have an important role among the class of new generation composite materials. FGMs are generally consist of two-phase composite material where their physical properties (modulus of elasticity, Poisson's ratio, density etc.) are defined in terms of continuously varying functions in desired directions. Their grading material properties can help to prevent undesired conditions by enhancing stabilization against temperature fluctuation, or by increasing the strength under variable load conditions. Some application fields of functionally graded materials can be given as biomedical devices, suspension systems, and automotive turbochargers. Increasing demand for composite helices (e.g. carbon or glass fiber helical/coil springs) has also revealed the need for optimizing the structural behavior. Advancements in technology and new approaches (like 3D printers) present an opportunity to manufacture functionally graded helical structures. In this study, static analysis of axially functionally graded circular helical springs having rectangular cross-section is performed by using mixed finite element method based on the Timoshenko beam theory. Two-noded curved mixed finite element has twelve degrees of freedom at each node which are three displacements, three cross-sectional rotations, three forces, two bending moments and a torque. The mixed finite element formulation is further improved by considering warping effect for the non-circular cross section via displacement-type finite element. Axially FG material properties are defined as continuously changing material properties along the axis of helical spring. The FG material is

considered as metal matrix reinforced by ceramic particle. The mixture rule is employed while defining the material properties of FG. Static behavior of axially FG circular helical springs is investigated under several boundary conditions and material gradient indexes. The results of the analyses are discussed over deformations and support reactions. Also, the results are verified by the commercial program ANSYS with three-dimensional brick elements (SOLID186). Several benchmark examples are presented to the literature.

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abst. 1066
"Amarcord"
Thursday
September 1
14h15

Strength prediction of hybrid bonded bolted joints for steel structures

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Hybrid joints that combine pre-tensioned bolts and adhesive bonding allow connecting parts to be compact and can accelerate steel structures' joining work. However, combining two technologies makes strength prediction more complicated. This study conducts bi-axial tests with various normal and shear forces to simulate local states in the hybrid joint and developed a probabilistic strength prediction from the bi-axial test results. It predicted the strength of hybrid joints with reasonable accuracy. Further investigation extends to the effects of surface roughness and adhesive properties on the joint capacities. The results of this study can contribute to the design to consider surface conditions, adhesive properties, bolt pretensions, and joint dimensions.

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abst. 1080
"Amarcord"
Thursday
September 1
14h45

Sustainable reuse of construction, demolition and excavation waste in urban constructions: examples of circular economy in the Republic of San Marino

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The generation and accumulation of solid waste represent some consequences of the urban development and the social growth. In parallel, the depletion of natural resources and raw materials is a significant issue that cannot be ignored. In this context, the idea of circular economy should become more and more popular as the solution that could put a limit to this inefficient cycle of manufacturing and subsequential disposal. This virtuous behavior is supported by the reuse of stuffs and recycling of wastes, which entail the decrease of raw materials consumption, the reduction of the energy needed for manufacturing and construction projects, the decrease of pollution related to the transportation of virgin materials, and the landfill emptying. Nowadays, construction and demolition wastes, as well as earth and rocks coming from building sites, represent the primary source of refuses which mainly affects developed countries [1]. Quantitatively, they can be esteemed as five times bigger than domestic wastes. According to the principles of circular economy, instead, the resources should be kept inside the economic system for more cycles, gaining an improved value in consecutive production phases. Therefore, researchers in the civil engineering field are working hard to develop innovative and eco-friendly technologies, based on analytical or numerical approaches, which aim at recycling this kind of waste, in order to reduce the environmental impact of buildings and infrastructures. For instance, a new way to conceive the project and management of infrastructures could be defined. Thus, recycled materials, which have undergone proper treatments, could replace traditional virgin constituents, in both maintenance works and construction of new roads. In this circumstance, in fact, the same materials obtained and accumulated during the demolition and preparatory phase could find a new application [2]. In the construction sector, instead, sustainable and eco-friendly materials and techniques can be employed to reduce the amount of virgin aggregates excavated from the ground. The decrease of such a considerable quantity of aggregates and cement represents a major point aiming at a more sustainable design [3]. Thus, recyclable constituents should progressively replace virgin components. These ideas

could find fertile ground in the Republic of San Marino, where a proper plan concerning the reuse of construction and demolition waste in buildings and road infrastructures should be followed, aiming at a system based on circular economy. The main aim of this research, in fact, consists in the identification of potential strategies to make the country more environmentally sustainable, leading the political and social choices toward a greener economy. Acknowledgements: Financial support from the University of the Republic of San Marino in the framework of the Research Project 2021: "Riutilizzo dei materiali da demolizione e delle terre da scavo per l'economia circolare delle opere di costruzione e manutenzione delle infrastrutture viarie: sviluppo e proposte di applicabilità nella Repubblica di San Marino" is gratefully acknowledged. References: [1] Arulrajah A., Piratheepan J., Disfani M.M., Bo M.W. Geotechnical and geoenvironmental properties of recycled construction and demolition materials in pavement subbase applications. Journal of Materials in Civil Engineering (2013), 25, 1077-1088. [2] Graziani A., Grilli A., Mignini C., Balzi A. Assessing the Field Curing Behavior of Cold Recycled Asphalt Mixtures, Advances in Materials Science and Engineering (2022), vol. 2022, Article ID 4157090, 13 pages. [3] Oikonomou N.D. Recycled concrete aggregates. Cement Concrete Composites (2005), 27, 315-318.

Applications- Material Science: glass manufacturing, polymers, and crystals (chaired by G Ulian, D Moro, G Valdre')

abst. 1081
"Amarcord"
Thursday
September 1
14h00

Recycle and Reuse of plastics and their environmental impact: NU.MA 4.0 project

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This project aims at evaluating the environmental impact related with industrial product manufactured via recycled plastics. The use of such materials should be proven in terms of chemical and mechanical properties of the novel material used in the production. This allows a small/negligible use of the raw materials at the end of the cycle. Most of the considered recycled plastics are polyethylene (PE) and polypropylene (PP) which mostly come from the everyday use of plastics in our modern society. Such materials are collected via milling of production of industrial artefacts or from third parties who need to get rid of such waste which can be reused. Comparisons and analysis are performed in terms of chemical analysis such as melt-flow tests as well as mechanical testing and numerical simulations of the specimens for future industrial applications and verification. Acknowledgements: This work has been supported by "Alma Idea 2022" Linea di Intervento B (CUP: J33C22001420001) and by the financial support of Italian Ministry of Industry incentives (MISE) for RD law 30/12/2020, n. 178.

Applications- Physics and Material science

Mechanical-thermal-chemical coupling response of polymer bonded explosives under low velocity impact

abst. 1002
"La Dolce Vita"
Thursday
September 1
11h30

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The energy localization mechanism of polymer bonded explosives under low velocity impact originates from the mechanical response. The ignition is induced due to the mechanical-thermal-chemical coupling process. In this process, the friction between the microcrack surface is the main in hotspot formation. Steven test as typical low velocity impact ignition test was simulated by Visco-SCRAM model and a friction-based hotspot model. The effect of the impact velocity, specimen size and projectile shape on ignition was discussed. Multiple impact was conducted to understand the relation between the damage accumulation and ignition. A tension-compression asymmetrical microcrack evolution was used to improve Visco-SCRAM model. The nucleation depended on the tension or compression condition and the growth followed the law of energy-release rate. The heterogeneous characteristics including microcrack length and density of microcracks was considered to produce the ignition uncertainty. The relation between the ignition and the heterogeneous microcrack was further analyzed.

Keynote Lecture

abst. 2001
"Amarcord"
Thursday
September 1
09h00

On the Fracture Toughness of Advanced Materials

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Fracture mechanics experimental tests are assuming an increasingly important role in the context of methodologies aimed at characterizing the mechanical behaviour of materials and structures. As a matter of fact, the knowledge of the parameters that characterise the ductility or brittleness of advanced materials is becoming a fundamental element for safety problems. Consequently, methods that seemed limited to highly specialized sectors of aeronautical and nuclear engineering are rapidly spreading to a more traditional sector, such as that of mechanical and civil engineering. This results, for example, in the extension to concrete and rocks of regulations that were initially limited to metallic materials. In such a context, the present lecture is focused on two types of advanced materials, that is: cement-based reinforced materials and nanomaterials, proposing for each of them a method to compute the fracture toughness. More in detail, in the context of cement-based reinforced materials a modified formulation of the Two-Parameter Model (TPM) is proposed. On the other hand, in the context of nanomaterials the non-local Stress-Driven integral Model (SDM) is proposed.

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abst. 2002
"Amarcord"
Thursday
September 1
09h30

Structural fatigue reliability design and optimization under uncertainty

Zhu, Shun-Peng (zspeng2007@uestc.edu.cn), University of Electronic Science and Technology of China, China

Fatigue is one of the most encountered problems with dynamically loaded engineering structures. Initially, to ensure the fatigue damage evolution during operation under perfect control, accurate lifing models by abundant experiments and full understanding of fatigue mechanism have been developed, ensuring that the designed structures with sufficient fatigue strength under predefined service condition. Unfortunately, it was later found that the fatigue performance is affected by multi-source uncertainties, including those arising from material property, load spectrum, geometrical dimension etc. In particular, sometimes, the computation is very sensitive to tiny changes in the inputs, varying quantities over reasonable ranges can even lead to outputs with 1000 times difference. Under this circumstance, traditional deterministic models no longer work, and methods developed from probabilistic perspective with well description on uncertain inputs are highly expected. To boost the development on probabilistic fatigue modeling and emphasize its crucial significance in fatigue reliability design and optimization, this study systematically recalls the theoretical basis and recent progress in this field, and ends with discussions as well as conclusions and future prospect.

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abst. 2003
"Amarcord"
Wednesday
August 31
12h00

Highly efficient numerical methods for derivative pricing

Ballestra, Luca Vincenzo (luca.ballestra@unibo.it), Alma Mater Studiorum University od Bologna, Italia

Derivatives are massively traded on the everyday financial markets. Their pricing involves two main steps: the construction of appropriate stochastic models for the dynamics of the underlying asset(s) and the application of analytical techniques or computational methods for computing a "fair" price based on the chosen models. These steps must be done with care if the goal is to obtain accurate derivative prices. In particular, if either the model selected or the derivative itself is particularly complex, the second step requires some numerical approximation. In this talk, we will present high-order numerical methods for pricing derivatives based on both single- and multi-factor models. We will propose very efficient approaches, based on the so-called repeated Richardson extrapolation in both space and time, which allow us to obtain accurate and fast approximations of option prices. Exotic options, such as options with a double barrier, and commodity derivatives will also be considered.

Advanced Fracture Simulations of Large Composite Structures

abst. 2004
"La Dolce Vita"
Thursday
September 1
09h00

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With a length of over 100 m, composite wind turbine blades are among the largest single components in the world made of fiber composite materials. Working in harsh environments and under complex loading, such large composite structures must maintain their structural integrity and reliability. The wind energy industry urgently needs more accurate and much faster modeling and simulation techniques to evaluate various structural designs toward more damage tolerant blade structures. In this lecture, the latest research and innovation in high-performance modeling techniques of large-scale blade structures and their components will be presented. Particu-lar focus will be placed on advanced finite element modeling techniques that can accurately predict complex fracture and damage phenomena in full-scale wind turbine blade structures and their critical structural details. With equal importance, simulation efficiency and calculation speed are greatly escalated to an unparalleled level by several recently developed key enabling technologies which will be introduced and demonstrated in this lecture.

Modelling of advanced composite materials

abst. 2005
"Amarcord"
Wednesday
August 31
10h30

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A multiscale modelling of three-dimensional knitted spacer composites is presented. A full-field finite element homogenization is carried out at each identified microstructural level and it is used at each upper level through transferring of information between different length scales in a staggered manner. A comparison between models and experiments is presented showing a good correlation both in terms of details in the architecture and mechanical properties.

Multi-scale reliability-based design optimization of tow-steered composite laminates

abst. 2006
"La Dolce Vita"
Wednesday
August 31
10h30

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3D printers and automated fibre placement machines have allowed the introduction of Variable Angle Tow (VAT) composites that, allowing the fibres to be relaxed along curvilinear patterns, offer greater tailoring capabilities than classic CFRP laminates. Nevertheless, the steering of brittle fibres is not flaw-exempt and, in fact, is greatly affected by the printer signature. In this work, we explore the use of multi-scale, high-order finite elements based on the Carrera Unified Formulation (CUF) to demonstrate the importance of manufacturing defects on the mechanical response and the reliability-based design of VAT composite laminates. In detail, the effect of fibre waviness, gaps, overlaps and micro-scale defects variation on the buckling and vibration response as well as on failure onset are investigated by using Monte Carlo analysis and stochastic random fields. Eventually, the use of metamodels and evolutionary algorithms are proposed and validated for uncertainty quantification and robust design. One of the main scope of the work is to show that high-order, multi-scale structural modelling based on component-wise kinematics can be helpful to broaden the design space that classical structural theories may have shrunk.

Computational tools: Closing the gap between mechanics and materials science

abst. 2007
"Amarcord"
Wednesday
August 31
09h30

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In the mechanics of heterogeneous materials – in particular, in the effective media theories – quantitative modeling focuses, mostly, on inhomogeneities (inclusions, pores, cracks) of the ellipsoidal shapes and the classic results of Eshelby are utilized. However, inhomogeneities in real materials (ceramics, geo-materials, metals) tend to have highly "irregular" shapes. The question arises, of quantitative characterization of such microgeometries and on extending the effective media theories to them. This challenge can be rephrased as bridging the gap between mechanics (quantitative methods) and materials science (largely observational). The progress that has been achieved recently in this direction will be reviewed.

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abst. 2008
"La Dolce Vita"
Wednesday
August 31
11h30

High dissipation metamaterials

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The main focus is on high-performance metamaterials featuring a periodic distribution of highly tunable infinite-dimensional resonators. The resonators are first treated as linear systems exhibiting eigenspectra with distinct features. Then these resonators are enriched by geometric and hysteresis nonlinearities. The band gap structure is investigated showing its sensitivity with respect to the design parameters. The nonlinear wavefrequencies and waveforms away from internal resonances obtained via a perturbation approach are shown to exhibit a high nonlinear tunability which is a key for advanced applications. Various metamaterial samples are 3D printed and tested experimentally using a 3D laser scanning vibrometer system to show very interesting stop band behaviors.

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abst. 2009
"La Dolce Vita"
Thursday
September 1
10h30

Finite Line Method for Thermal Stress Analysis of Composite Structures

Gao, Xiao-Wei (xwgao@dlut.edu.cn), Dalian University of Technology, China

In this paper, a completely new collocation type numerical method, Finte Line Method (FLM), is proposed for solving general engineering problems governed by second or high order partial differential equations with proper boundary conditions. The method is based on the use of finite number of lines crossing each collocation point, and the Lagrange interpolation formu-lation is used to construct the shape functions for each line. When the number of the finite lines exceeds the dimension of the considered problem, the Least-Square technique is applied to all lines' equations to form an equation set to solve the first and high orders of partial derivatives of any physical variables with respect to the global coordinates. Then, the derived spatial partial derivatives are directly substituted into the governing partial differential equations and related boundary conditions to set up the system of equations with physical variables, temperatures and displacements, at all collocation nodes as unknowns. As an application, the proposed method is used to perform the thermal stress analysis of layered composite structures. A few numerical examples will be given to verify the correctness and stabil-ity of the proposed method.

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abst. 2010
"La Dolce Vita"
Wednesday
August 31
10h00

A Discontinuous Galerkin method for high fidelity multilayered composite shell analysis

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Advanced structural applications call for the development of numerical methods able to offer modelling flexibility as well as high computational performances. Among various computational approaches, the discontinuous Galerkin (DG) method is emerging as a powerful and versatile numerical technique for a wide class of problems. In DG methods the unknown fields are expressed by discontinuous basis functions, whose coefficients become the unknowns of the discrete problem. The continuity of the solution and the fulfilment of the boundary conditions are then retrieved in weak sense via suitably defined penalization boundary integrals. Despite the possible involvement of a large number of degrees of freedom and the computational effort needed for the evaluation of the mentioned boundary integrals, the discontinuous nature of the basis functions used in DG methods comes with some desirable features for computational modelling. Indeed, DG methods: i) offer high-order accuracy for conventional and non-conventional meshes, ii) simplify the implementation of hp adaptive mesh refinement schemes, iii) allow a straightforward coupling between different models in multi-physics simulations, and iv) allow massive parallelizations. These features justify the success of DG methods in several research areas of computational science. Composite laminated shells gained a principal role in lightweight structural technology as they allow, when optimized, significant weight savings and performance enhancements. Additionally, they can be used effectively in building geometrically very complex structures whose behaviour is significantly affected by the interplay among the inherent heterogeneity, the shell curvatures and the possible presence of cut-outs. On the other hand, the accurate appraisal of the laminated shells structural response appears crucial to fully attain their potential. Thus, due to the high number of involved design possibilities and the inherent complexity of the multilayered shell problem the development of accurate numerical models is then mandatory. In view of the above presented framework, in this work, a novel DG-based formulation for the analysis of composite multilayered shells is presented. The shell geometry is represented via either analytical functions or NURBS parametrizations, while generally shaped cut-outs are defined implicitly within the shell modelling domain via a level set function. Models are presented for different order shell theories introduced via the Carrera Unified Formulation, which is used to describe the covariant components of the displacement field throughout the thickness. The shell governing equations are then derived from the Principle of Virtual Displacements and solved via an Interior Penalty discontinuous Galerkin method over a discretization of the shell modelling domain that is obtained by intersecting a background structured grid with the level set function defining the cut-outs. High-order accurate quadrature rules for implicitly-defined regions are employed to compute the integrals of the method. The combined use of these features provides a high-fidelity approach to the analysis of multilayered shells with cut-outs. Numerical results are present tor static, buckling and dynamic shell analysis to show the approach capabilities.

Sensitivity of confinement to pointwise variability of stresses in non-circular cross sections and effective strain in wrapping jackets

abst. 2011
"La Dolce Vita"
Wednesday
August 31
12h30

Lignola, Gian Piero (glignola@unina.it), University of Naples "Federico II", Italy

New advanced composite materials such as Fiber-Reinforced Polymer (FRP) or Fiber Reinforced Cementitious Matrix (FRCM - where the organic matrix of FRP is substituted by an inorganic matrix) improved the industry of masonry and concrete confinement by means of easily and effectively wrapping layers of fibers around the columns. Several studies showed that circular cross sections gain a meaningful increase in strength and ductility when wrapped with high performance materials. Available analytical models for the assessment of the stress–strain behaviour of confined columns are easily derived for cylindrical plain solids. However square- and rectangular-cross section columns are typically found in real structures and it was clearly observed that they suffer reduced increases in terms of strength and ductility compared to their circular counterparts. Reason for lower performance of square and rectangular cross sections is the non-uniform distribution of lateral confining pressure, having a peak at the corners of cross sections along the diagonals and much lower pressure between them. A practical solution for the evaluation of confinement effectiveness for such non-uniform pressure field was found involving unconfined parabolic regions of the cross section and counterparts fully confined. At the same time transmuting a quadrilateral section into an equivalent circular section (e.g. inscribed, circumscribed, or with same area). This simple method showed to have significant drawbacks, hence a more refined method is proposed. The proposed method accounts for the pointwise variable principal stress state in the cross-section by means of a detailed analysis of the stress field through Mohr's circles. The final goal is to provide the mean integral value of the stress field in a simplified closed form solution of an effective equivalent pressure. This equivalent pressure inserted in triaxial confinement models allows to describe the particularities of non-axisymmetric cross sections, namely square and rectangular. This simplified model is the basis for a more refined iterative confinement model to evaluate the entire stress-strain relationship of confined solids. Models aimed at directly evaluate the confined strength depend on a supposed ultimate strain value for the wraps. It is commonly supposed that wrap fails at the same tensile strain of confining material, as it can be reached in a flat coupon test. In reality, experimental tests demonstrated that in most cases, peak confined strength is not reached experimentally at ultimate tensile strain of the jacket. The discrepancies may include the shape and sharp cracks of substrate as well as stress concentrations or defects in the wraps (namely, the multiaxial stress state in the jacket wrapping or wavy initial configuration of fibers). The average absolute error of confinement models usually had notable reductions when effective hoop strain (less than ultimate value) is inserted in direct models, e.g. by means of strain efficiency factors (i.e. strain ratio between the effective hoop strain at failure and the flat coupon test results). Accounting for the 3D evolution of stresses and strains in confined solids and wrapping jackets allows to simulate satisfactorily all this peculiarities in the stress-strain relationships for confined non-circular solids.

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abst. 2012
"Amarcord"
Wednesday
August 31
11h30

Bonded joints. Are probabilistic methods a way to get rid of fudge factors?

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Adhesive bonding is increasingly being considered by engineers for load-bearing joints to complement, or supplement, traditional mechanical fasteners for a large variety of structural materials, including fibre-reinforced polymers, timber, and steel. However, practitioners are still largely applying dimensioning methods that rely heavily on fudge factors. This is not due to the relative novelty of the joining technique, and the complexity of the associated mechanics. This paper guides the reader through some of the most important aspects of adhesively bonded joints, and the reasons why classical mechanics can only be applied in conjunction with fudge factors. Subsequently, the principles of fracture mechanics (FM) are presented; it is shown that, despite its conceptual strengths, FM is rather difficult to implement, as it introduces mechanical concepts practitioners are not familiar with. Then probabilistic methods (PM) are introduced; it is shown that PM can be considered as an extension of classical mechanics, as it can be easily implemented as a post-processing routine of the latter. Additionally it is shown that PM, unlike FM, neither require specific tests procedures for characterisation, nor complicated numerical analyses. Lastly, the paper offers a step-by-step guide for the implementation of PM for the dimensioning of adhesively bonded joints. The second part of this paper illustrates the latter on a series of examples involving FRP, timber, and steel.

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abst. 2013
"Amarcord"
Thursday
September 1
10h00

Analysis and modelling of RC elements strengthened with composite under vibration and static test

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In recent years one of the most essential duties for civil engineers is to develop rehabilitation solutions both for historic and modern structures. Reinforced concrete (RC) is a relatively modern construction material, and it can be often damaged both with cracking due to loading or corrosion of reinforcement. The Near Surface Mounted (NSM) technique of inserting Fiber Reinforced Polymer (FRP) rods into grooves has been shown to be a suitable method for repairing damaged RC elements. This work elaborates considerations on NSM Carbon-FRP and Glass-FRP rod strengthening based on results of an experimental investigation using bending tests on non-strengthened beams and strengthened with NSM C-GFRP rods and, lastly, through vibration tests on the beams mentioned above. The experimental bending tests were performed on the RC beams for defining static behaviour until failure. Given that damage in concrete elements leads to a change in dynamic response, vibration tests were carried out to evaluate the experimental vibration both for non-strengthened and strengthened beams with NSM C-GFRP rods. Envelope of Frequency Response Functions (FRFs) is obtained, and frequency values variations are related to the damage degree of beam models subjected to static tests. Finally, a comparison between data obtained by finite element analysis and experimental results leads to discussing the actual behaviour of RC beams strengthened using NSM strengthening technique and assessing the availability of CFRP and GFRP rods.

Study on the Automatic Optimization Design of the Cross-Sectional Layout of an Umbilical with Layers Based on the GA-GLM

abst. 2014
Repository

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Marine umbilical provides the remote control function for offshore oil and gas exploitation, which is usually integrated by different functional components that vary widely in their mechanical properties. Under the action of external load, unreasonable cross-sectional layouts may lead to large cross-sectional deformation and contact pressure between components thus affecting the service life of an umbilical. Therefore, how to design the cross-sectional layout is a very necessary research work in order to improve service life of the umbilical to withstand various loads during operation. At present, the research on the cross-sectional layout of an umbilical is not sufficient, and there is no standardized design method in the design specification. Considering the mechanical and geometrical properties as the quantitative design objectives, the mathematical optimization model of the cross-sectional layout of an umbilical is proposed. Meanwhile, the layering strategy is introduced because of the processing and manufacturing factors. Then, the genetic algorithm (GA) with good global search performance and the generalized Lagrange multiplier (GLM) with fast convergence speed are combined to solve the above model. Finally, taking an umbilical as an example, the optimal cross-sectional layout is obtained and the effectiveness of the algorithm is verified by the numerical simulation. The results show that the optimization method proposed in this paper can quickly obtain the optimal design cross-sectional layout, and supply a specific way for the fast design of an umbilical, which has the certain engineering application value.

State of the art and perspectives for reduced order modelling in computational fluid dynamics: applications in industry, medicine, and environmental sciences

abst. 2015
"Amarcord"
Thursday
September 1
10h30

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We provide the state of the art of Reduced Order Methods (ROM) for parametric Partial Differential Equations (PDEs), and we focus on some perspectives in their current trends and developments, with a special interest in parametric problems arising in offline-online Computational Fluid Dynamics (CFD). Efficient parametrisations (random inputs, geometry, physics) are very important to be able to properly address an offline-online decoupling of the computational procedures and to allow competitive computational performances. Current ROM developments in CFD include: (i) a better use of stable high fidelity methods, considering also spectral element method and finite volume discretisations, to enhance the quality of the reduced model too, and allowing to incorporate some turbulent patterns and increasing the Reynolds number; (ii) more efficient sampling techniques to reduce the number of the basis functions, retained as snapshots, as well as the dimension of online systems; (iii) the improvements of the certification of accuracy based on residual based error bounds and of the stability factors, as well as the guarantee of the stability of the approximation with proper space enrichments. For nonlinear systems, also the investigation on bifurcations of parametric solutions are crucial and they may be obtained thanks to a reduced eigenvalue analysis of the linearised operator. All the previous aspects are quite relevant in CFD problems to focus on real time simulations for complex parametric industrial, environmental and biomedical flow problems, or even in a control flow setting with data assimilation and uncertainty quantification. Model flow problems will focus on few benchmarks, as well as on simple fluid-structure interaction problems and shape optimisation applied to some industrial problems of interest.

A study on the optimal curing process of tow-preg laminated composites through multi-scale computational modeling

abst. 2017
"Amarcord"
Wednesday
August 31
12h30

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Despite the development of composite application technologies in recent decades, the manufacturing process that greatly affects the performance of composite materials still depends on the empirical approach, and the understanding of the physical phenomena occurring during the manufacturing process is insufficient. The key in the composite material manufacturing process is to minimize the pores inside the resin by uniformly impregnating it between the fiber bundles. Since most of the previous studies analyzed the flow of resin during the process on a single scale, there was a limit to accurately predicting the effect of the process on the properties of the composite materials. In this study, through multi-scale analysis, from the fiber unit distribution to the resin flow in the composite laminate, the optimum curing cycle was suggested to reduce the pores and enhance the physical properties of the composite material.

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abst. 2018
"Amarcord"
Wednesday
August 31
10h00

Structural optimization by fibre fused filament fabrication

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Fibre-reinforced composites (FRCs) are advanced materials widely used in the aerospace, automotive, and naval industries. Advancements in additive manufacturing (AM) technologies such as continuous fibre fused filament fabrication (CF4) allow the layer-by-layer printing of FRCs with a spatial in-plane variation of the fibre orientation and fibre volume fraction, thus expanding the design space for variable and constant stiffness laminates. With these offered degrees of freedom, computational design tools such as topology optimization (TO) are essential to optimized layout designs that take advantage of FRC materials' anisotropic properties. However, most design approaches either do not take complete advantage of this extended design freedom or fail to consider CF4 constraints. We present a simultaneous topology and stacking sequence optimization for variable composite laminate structures. The proposed method integrates the geometry projection (GP) and the solid isotropic material with penalization (SIMP) to effectively perform the arrangement of FRCs material in each lamina, enabling spatial in-plane variation of the fibre orientation and fibre and matrix volume fraction. In addition, lamination parameters (LPs) are used as design variables to extend the approach to design variable composite laminate, considering only in-plane stiffness. In the outcomes, various benchmark problems are considered to demonstrate the applicability of the proposed method. Lastly, to illustrate the practical relevance, the attained designs are fabricated employing CF4.

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abst. 2019
"La Dolce Vita"
Wednesday
August 31
12h00

Sea climate changes and state of marine renewable energy in Italy

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Renewable energy has developed rapidly in Italy over the past decade and provided the country a means of diversifying from its historical dependency on imported fuels. Marine renewable energy is going to give a huge contribution in the next decades in the diversification of sources. Italian Regions on the Sea will contribute to a rapid development of new installation of devices for marine renewable energy the ecological transition to reach the challenge of a carbon free country in 2050. The speech will present a review of the expected sea climate conditions by 2100 in the Italian Seas and the recent strategy foreseen to generate clean energy from the Sea.

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abst. 2021
"La Dolce Vita"
Wednesday
August 31
09h30

Effect of a mixture of layers reinforced with carbon nanotubes and graphene platelets on the flutter of hybrid panels

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This study aims to investigate the flutter of hybrid nanocomposite panels under supersonic flow. The hybrid composite panel incorporates layers made of the polymer matrix with different nanofillers such as carbon nanotubes (CNTs) and graphene nanoplatelets (GPLs). The effective Young's and shear moduli of each CNTs and GPLs layers are determined by Mori-Tanaka scheme and modified Halpin-Tsai homogenization technique, respectively. Poisson's ratios and mass densities are determined according to the rule of mixtures. The displacement gradients of the panel are assumed to be small so that the components of the Green-Lagrange strain tensor are linear and infinitesimal. Additionally, the first-order shear deformation theory and the first-order piston theory are applied to formulate the aeroelastic model. The element-free IMLS-Ritz method with meshless features is employed to discretize dynamic equations and define multi-parametric characteristic equations functionally dependent on material and geometric parameters of the panel. The accuracy of the obtained solution and results is examined by comparing determined natural frequency and critical aerodynamic pressure with those from simpler panel models presented in the literature. Then, a comprehensive parametric study is carried out to show effects of hybridization of different distribution patterns of CNTs and GPLs, weight fractions, total layer number, and aspect ratio of hybrid composite panels on their flutter bound.

Soil-Structure-Interaction (SSI) Modelling For Deep Foundations

abst. 2023
"La Dolce Vita"
Thursday
September 1
09h30

Dezi, Francesca (francesca.dezi@unirsm.sm), University of the Republic of San Marino, San Marino

Damage sustained during past earthquakes has highlighted that the seismic behaviour of structures and infrastructures is highly influenced by the response of the soil-foundation system. For this reason, modern seismic codes have started, at least in particular cases, to address the design and the verification of the structure, its foundation and the local deposit as a whole system. The substructure method plays a significant role for performing soil-structure interaction analysis allowing the analysis of the soil-foundation and superstructure subsystems separately and a more easily identification of their dynamic behaviours through the use of dedicated software. In the framework of the substructure method, the dynamic response of soil-foundation systems in the case of deep foundations can be studied with different approaches. The goal of this presentation is to present a general overview of analytical and numerical procedures for the dynamic analysis of soil-pile foundation systems subjected to the propagation of seismic waves in the soil. Both single piles and pile groups with general layouts (including pile inclination) embedded in homogeneous as well as in inhomogeneous soil profiles are addressed. The procedures presented herein may be used in practice or in research to obtain realistic estimation of the dynamic impedances, the foundation input motion and stress resultants along piles. Finally, the results of different in situ experimental campaigns conducted on deep foundations are shown and compared to those obtained by some of the above mentioned numerical procedures.

Effects Of Soil-Structure Interaction On The Seismic Response Of Bridges

abst. 2024
"La Dolce Vita"
Thursday
September 1
10h00

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Dynamic Soil-Structure Interaction (SSI) is known to be a factor that can significantly affect the seismic response of bridges. When this is the case, the structural model used in the analyses should be able to take into account, as rigorously as possible, the complex dynamic response of foundations, which is characterized by a frequency-dependent behaviour. For time domain applications, which are generally more familiar to engineers and are mandatory in case of nonlinear structural behaviour, the sub-structure approach can be suitably adopted to perform SSI analyses, by supposing the foundation to behave linearly, consistently with hierarchy principles of modern codes. The frequency-dependent of the soil-foundation systems are simulated through suitable Lumped Parameter Models (LPMs) in a sub-structuring scheme, able to simulate the frequency-dependent nature of the soil-foundation system dynamic behaviour. The presentation aims to address the methodology for including SSI effects in the linear and nonlinear seismic analysis of bridges founded on piles, exploiting common software for structural analysis and suggesting simple and efficient LPMs. In addition, an overview of the SSI effects on the dynamic response of bridges is presented, starting from phenomenological investigations based

on simplified models, and passing through applications to real case studies representative of multi-span bridges, arch bridges, and isolated overcrossings.

Methods- Data Science and Data analysis

Machine learning frontiers for the exact sciences: anomaly detection, data driven theory and experimental design

abst. 1028
"Amarcord"
Thursday
September 1
15h00

Murari Andrea (andrea.murari@istp.cnr.it), Consorzio RFX, Italy

Until recently, science has progressed mainly in a hypothesis driven way: based on established theories, new models have been developed mathematically and falsified with specifically designed experiments. This methodology has been very successful in the past but its limitations are evident in its application to open systems, due to their complexity, uncertainties and nonlinearities. Therefore, a lot of untapped knowledge remains buried in the large stored warehouses, consequence of the lack of adequate mathematical tools for data mining. The present contribution provides an overview of recent developments in machine learning (ML) and statistics, to address three of the most challenging issues in data analysis for the science of complex systems: causality detection, data driven modelling and the design of new experiments. In many scientific fields, the majority of the signals consist of time series, whose causality interrelations are very often not straightforward to determine. Predicting the evolution of the systems under study can therefore become very challenging, particularly in no stationary situations. On the other hand, recently an impressive series of upgrades of machine learning techniques have been devised to forecast even rare catastrophic events, for examples disruptions in tokamaks. These new solution try to equip ML tools with human cognitive skills, such as the capability of learning from few examples, of adapting to new situations and of transferring knowledge from one problem to another. The extraction of mathematical models from cross sectional data is a great challenge in case of large database such the one of CERN or the Joint Europe Torus (JET), the largest tokamak ever operated in the world. A new data driven theory approach, called Genetic Programming supported Symbolic Regression (GPSR), has been recently developed to address problems, for which it is difficult to derive models from first principles. A typical example of SR via GP application is the extraction of scaling laws and the identification of dimensionless quantities. The deployment of these tools to study large databases has shown that the traditional power laws are not the best mathematical forms to represent scaling, motivating a complete revision of the underlying scale invariance assumptions. Traditional ML and statistical tools are predicated on the assumption that the data are independently sampled from completely stationary systems. A typical violation is the planning of new experiments; the available models have to be applied to new regions of the operational space, not represented in the previous data. A new genetic programming procedure has been finalised to extract from past data to identify the best region of the operational space to plan new experiments, with potential savings even of the order of 50% of the experimental time on JET. In addition to exhaustive numerical tests to prove the generality of the techniques, specific applications to the thermonuclear fusion and the earth sciences will be discussed.

Methods- High performance computing, Algorithms and Programming languages

abst. 1042
"Amarcord"
Thursday
September 1
15h15

A High-Performance Computing Hybrid Cluster

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Considering the computational complexity of today's problems, the need for high-performance computing resources is growing more and more. At the heart of High-Performance Computing (HPC) there is certainly the management of computational workloads where parallel computing is typically used to achieve high performance in data processing. The focal point of enabling high-performance processing is the result of cooperation of multiple layers: application, middleware and hardware. It is important to note that any hardware or software difference between nodes of the system can affect the performance of the workflow. Consequently, the choice of components is crucial. In a cluster, whose purpose is HPC, the collaborating nodes must be connected through high-speed connections. InfiniBand technology is an high-speed and low-latency communication standard for this purpose, as borne out by its use in many of the most powerful supercomputers in the world according to the Top500 ranking. Although HPC is a fast-growing industry, a dedicated IT cluster can also be designed to perform High Throughput Computing (HTC) tasks. If HPC activities are characterized by the need for large amounts of computing power over short periods of time, HTC activities also require intensive loads but for much longer time frames. To carry out both paradigms we have built a cluster with different technologies collaborating with each other, i.e. heterogeneous resources. The resources are allocated in the Scientific Data Center of the Federico II University of Naples and are funded by the IBiSCo project. In addition to implementing, validating and demonstrating in a fully operational and real environment a substantial strengthening of the scientific computing infrastructure in Southern Italy, already funded in the past by the 2007-2013 PON (e.g. PI2S2, SCOPE and RECAS projects) and the Fund for the ordinary functioning of the Ministry of Education, University and Research (MIUR), the aim of the IBiSCo project is to contribute significantly to the "Pillar 2: Infrastructure" of the "Important Project of Common Interest on High Performance Computing and Big Data Enabled Applications "(IPCEI-HPCBDA). The project is based on the desire to constitute the first real and concrete step towards the Italian IT and Data Infrastructure (ICDI), laying the foundations for its southern part (ICDI-sud) which will be part of the national project. The achievement of these objectives requires the creation of a digital platform for scientific and technological collaboration and co-creation. The project, carried out in collaboration with the Naples section of the National Institute of Nuclear Physics (INFN) and the SPIN and ISASI institutes of the National Research Council (CNR), allowed for the acquisition of resources for the calculation and conservation of data. The resources are aimed at general-purpose computing capable of responding to the various computing needs ranging from parallel applications for distributed memory systems, to applications that make extensive use of modern graphics accelerators, or that intend to experiment with hybrid parallelization paradigms.

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abst. 1068
"Amarcord"
Thursday
September 1
15h30

Numerical and experimental investigations of process- structure-interactions of fibre-reinforced thermoplastics while joining by plastic deformation

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The joining of fibre-reinforced thermoplastics (FRTP) by means of plastic deformation often results in a change of the internal material structure in the forming zone. Especially process- and material-related parameters have high influence on the local deformation behavior and therefor on the properties of the component. For the efficient design of such joining zones it is necessary to understand and predict the local material configuration induced by plastic deformation. These forming processes often take place above melting temperature of the thermoplastic matrix material. This allows the thermoplastic matrix to move through and along the fibres. Furthermore, the occurring phenomena of fibre reorientation and local change of fibre volume content caused by compression are driven by the displacement of the molten matrix. These phenomena are governed by the fibre stiffness and the dynamic viscosity of the molten matrix. The focus of the presented investigations is based on mechanical joining processes by means of plastic deformation. The experimental setup consists of a tapered pin, a heating element and a FRTP sheet. After heating up the composite of glas fibre (GF) and polypropylene (PP) above melting temperature, the tapered pin is pushed through the FRTP in thickness direction. Thereby the fibres and molten matrix are displaced radial and along the tool motion direction. These processes can lead to matrix rich zones, areas with a high fibre volume content and a reorientation of fibres in terms of shifting and bending. Detailed investigations were performed with varying tool geometry, process temperature, tool velocity and textile architectures of unidirectional and bidirectional material. In order to investigate the deformation phenomena, a numerical setup based on an Arbitrary-Lagrangian-Eulerian (ALE)–Method combined with a multi-filament approach is used. The validation of the numerical results are made with the experimental setup, which allows a comparison of the forming forces and the phenomenological description via computed tomography (CT) and micrographs. The numerical simulations also allow a detailed information about shear rates and pressure gradients in the forming zones during forming. Those parameters gain an in depth process knowledge and show the dependence between process parameters and local material structure.

Methods- Modeling and Simulations

abst. 1003
"La Dolce Vita"
Wednesday
August 31
14h00

Experimental and Numerical Investigations of Timber Floor Panels Under Dynamic Loading

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Glued-laminated timber, commonly referred to as glulam, is a structural timber product made from glued smaller pieces of wood elements. As glued-laminated timber can be produced in either straight or curved form, with the grain of all laminations essentially parallel to the axis of the member, the carefully prediction of the mechanical properties is very important. Firstly, four-point bending tests have been conducted until the failure of the glulam beams and these experimentally derived material properties were utilized in the subsequent numerical study. Secondly, two types of floor panels are studied. Each panel is composed of glued laminated beams and wood constituting the floor. The effects of the joints connections are investigated. The accuracy of the 3D model was assessed against previous results [Fuentes et al. 2014, Titirla et al. 2021]. After the validation of the model, the proposed FE model is used to investigate the dynamic response of these panels in different vibration loading. A dynamic analysis of a structure differs from a corresponding static analysis mainly in two ways. While a static analysis assumes that a structure is in complete equilibrium with its surroundings a dynamic analysis takes into consideration the structure's true response when subjected to a force. Furthermore, a static analysis treats the loads as static, which means that they varies sufficiently slowly with time. On the other hand, there are a lot of loads that in fact are dynamic, that is, they varies rather quickly with time. Vibrations may be described as oscillations around the statical equilibrium of a structure. Vibrations arise when time-varying disturbances, either forces or displacements, interact with the inertia properties of an affected medium. The dynamic response of a structural system is affected by the material properties, the properties of the system as whole, and the presence of non-structural elements, such as floor coverings, ceilings etc. As a result, in the present work attention is focused on the dynamic and vibroacoustic response of timber floor panels as well as the study of the effect of material anisotropic and the different types of assembly on its responses. Good agreement was shown and further useful results were observed. Keywords: Timber structures, dynamic analysis, vibroacoustic, numerical and experimental measurements, linear. 1. S. Fuentes, E. Fournely A.Bouchaïr (2014) Experimental study of the in-plan stiffness of timber floor diaphragms, European Journal of Environmental and Civil Engineering, 18:10, 1106-1117, DOI: 10.1080/19648189.2014.881760. 2. M. Titirla, S. Benakli, W. Larbi. Dynamic and vibroacoustic response of timber floor panels. Measurements and non-linear numerical simulations. Proceedings of the 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, COMPDYN 2021, online, Athens, Greece, June 28-30, 2021.

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abst. 1008
"La Dolce Vita"
Wednesday
August 31
14h15

Fast Semi-Analytical Finite Element for Bonded Joints to Describe Bonding Stress Concentrations

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Adhesively bonded joints typical exhibit highly localised stress states in the adhesive at the edges of the bonding area. If these stress concentrations are analysed based on the Finite Element Method, usually a high number of degrees of freedom has to be utilised in the adhesive due to very short run-out lengths of peeling and shear stresses. In order to extent the available element technologies for the computationally efficient analysis of such stress concentrations, an effective finite element approach is demonstrated based on a two-dimensional single lap shear joint. The finite element is derived based on a semi-analytical solution of the underlying equations. The semi-analytical solution and the resulting computational efficiency are achieved first by neglecting the in-plane material characteristics of the core

as the in-plane stiffnesses of the adhesive are very low with respect to the ones of the joining partners (cp. [Ban73] for justification of neglect). Secondly, it is accomplished through the assumption of a typical finite element displacement pattern of the joining partners and consequently by the available displacement continuity condition between the adhesive and the joining partners. As a result, a single inhomogeneous ordinary differential equation of the adhesive mid-plane displacement in the out-of-plane direction is derived. It is deduced by solving the underlying equations in the through-thickness direction of the adhesive (similar to the approach according to [Hem52] for sandwich beams) and by reducing the resulting equations to a single consistent one. If the mid-plane displacements in the adhesive are introduced as degrees of freedom at the element edges, the derived ordinary differential equation can be solved analytically. This solution consists of exponential functions enabling the description of very short run-out lengths of peeling and shear stresses. As a consequence, an algebraic deformation pattern of the adhesive is available enabling the formulation of a finite element for stress concentrations in adhesively bonded joints. In order to estimate the accuracy as well as the convergence behaviour of such an element approach, computation results for a single lap shear joint composed of Aluminium joining partners are compared with a numerical exact solution of the two-dimensional problem (as described in [Ban73] or alternatively derived according to [FBVS92] for sandwich beams) as well as with classical finite element simulations using the commercial finite element program Abaqus (Dassault Systemes SA, Paris, France). The computation results show that the proposed element technology enables a very high computational accuracy, in particular, concerning the stress concentrations in the adhesive although the necessary number of degrees of freedom are significantly reduced. The latter is shown based on systematic convergence studies indicating that only two to three elements are needed in the area of the adhesive edges in order to describe the stress concentrations of interest sufficiently. REFERENCES: FBVS92] Frostig, Y.; Baruch, M.; Vilnay, O.; Sheinman, I.: High-Order Theory for Sandwich-Beam Behavior with Transversely Flexible Core. In: Journal of Engineering Mechanics 118 (1992), May, No. 5, pp. 1026–1043. [Ban73] Bansemir, H.: Krafteinleitung in versteifte orthotrope Scheiben. In: Ingenieur-Archiv 42 (1973), pp. 127–140. [Hem52] Hemp, W.S.: On a Theory of Sandwich Construction. A.R.C. Technical Report RM. 2672. 1952

A computational framework for multi-stability analysis of laminated shells

abst. 1020
Repository

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The multi-stability of composite shells often exhibits complex mechanical behaviors, accompanied by large deformation, strong nonlinearity and multiple equilibrium branches. We present a numerical framework for stability analysis of laminated composite shells, which is capable of efficiently computing nonlinear equilibrium paths and critical points, and effectively assessing the stability of the structure's equilibrium. The computational framework is applied to investigate several multi-stability problems in cylindrical laminated shells. Good agreement is observed even in an "extreme" experimental case where the multi-stability is highly sensitive, and it is found that the precise approximation of the strain energy is crucial for accurate prediction of shell stability. This study is believed to provide a powerful alternative to other methods for the stability analysis and the design of advanced composite shell structures.

Influence of CNTs properties' uncertainty in functionally graded plates' behaviour

abst. 1026
"Amarcord"
Thursday
September 1
12h30

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Carbon nanotubes (CNTs) are widely used as material reinforcement in the most diversified fields of engineering. Being their contribution significant to the mean properties of the materials thus reinforced, it is very important to assess the influence of CNTs properties' variability on the response of the resulting materials. For this purpose, in this work one considers functionally graded plates (FGPs) constituted by an aluminium continuous phase reinforced with CNTs. The CNTs' volume fraction evolution through the thickness is responsible for the plates' functional gradient. Since the present work aims to evaluate the influence of geometric and material CNTs properties on the static and free vibration response of FGPs, a data sample of those types of inputs, was randomly generated. With the results obtained, namely concerning neutral surface shift, shear correction factor, maximum transversal deflection and free vibration frequencies, multiple linear regressions were performed to assess the influence of the different inputs considered for this purpose. From the preliminary analysis of the multiple linear regressions results, the influence of the CNTs' outer diameter on the response of the plates stands out against the remaining inputs, both in terms of static and free vibration behaviour. However, for all the considered outputs, the models with the inputs CNTs' outer diameter, length and Young's modulus present the best fit. Also, all the inputs are statistically significant. The fact that the quality and the significance of the fit improves with increasing power law exponents is also noteworthy.

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abst. 1027
"La Dolce Vita"
Wednesday
August 31
14h30

Numerical model of impact and fragmentation of interpenetrated composite

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The interpenetrating composites consist of a scaffold and metallic matrix, which fills it being introduced under pressure. The scaffold is usually crushable. In our case, the SiC material stands for the skeleton, while the AlSi12 alloy is the matrix. Both materials are crushable. The SiC phase is brittle throughout the loading process, but the AlSi12 alloy is brittle during the elastic phase; then, its behaviour becomes viscous-plastic. The presentation concerns the simulations of impact and fragmentation of metal matrix composite - AlSi12/SiC. The numerical model of the internal structure is created based on CT scanning. The microstructure of the composite is complex and consists of metallic phase (85%), ceramic SiC skeleton, porosity, and system of not perfect interfaces. The impacts are realized in the following few scenarios. The exemplary scenario is realized by imposing the initial conditions on the sample that hits a hard elastic barrier. The second one corresponds to SHPB experiments. The last one is the hitting of an elastic impactor against the sample. The influence of the impact velocities and material parameters of the phases on the failure modes is observed. Previously, analyses of the modes of loading application on the micromechanical failure of metal matrix composite were analysed in [1, 2]. An analysis of the empty SiC scaffolds is presented in [3]. The proposed finite element model of the AlSi12/SiC composite behavior describing gradual degradation under impact loading was tested for different scenarios of hitting. In all cases, the growth of damage in the composite is very realistic. These results lead to the conclusion the proposed finite element model is very effective. Acknowledgment: The results presented in this paper were obtained within the framework of research grant No. 2019/33/B/ST8/01263 financed by the National Science Centre, Poland. The numerical analyses were done in the ICM UW in Warsaw, CYFRONET AGH in Krakow and in CI TASK in Gdańsk, Poland. References: [1] Postek, E. and Sadowski, T. Distributed microcracking process of WC/Co cermet under dynamic impulse compressive loading. Compos. Struct. (2018) 194: 494-508. [2] Postek, E. and Sadowski, T. Qualitative comparison of dynamic compressive pressure load and impact of WC/Co composite. Int. J. Refract. Hard. Met. (2018) 77: 68-81. [3] Postek, E., Sadowski, T. and Bieniaś, J. Simulation of impact and fragmentation of SiC skeleton, Phys. Letters (2021) 24:578-587.

Linear smoothed polygonal finite element method for modelling adhesively bonded interfaces

abst. 1033
"Amarcord"
Thursday
September 1
11h30

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The modeling of bonded interfaces is a challenging and computationally expensive task considering the fine discretization needed along the interface and the required damage models. Recently cohesive zone models (CZM) have been extensively studied to model interface fracture. However, from a computational efficiency point of view, efficient methods are required to model interfaces. Often interfaces are between components of varying thickness and material properties and hence, the substrates and interface have different stiffness. Thus coarse meshes would suffice at most of the geometry while demanding finer meshes at the interface for accurate solution failure predictions. This poses restrictions on meshing the overall geometry, thus increasing the number of nodes and the computational cost. In this work polygonal elements constructed based on a linear smoothed finite element method is proposed which allows for easy transition between the different mesh sizes without any compromise in accuracy. The numerical examples demonstrate the computational efficacy.

A new metamodeling method based on NURBS hypersurfaces for multiple-input multiple-output systems

abst. 1043
"Amarcord"
Thursday
September 1
11h45

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The more complex a problem the more resources its resolution requires. One way to overcome this issue is to model the system with different levels of fidelity depending on the type of physical response (i.e., scalar field, vector field, tensor filed etc.) and the required accuracy. For those responses which do not require a high level of accuracy, analytical, semi-analytical or low-fidelity numerical models can be used to describe the physical phenomena. Conversely, when the requirement of the accuracy becomes of primary importance, a high-fidelity model must be foreseen to correctly predict the physical responses. Nevertheless, a high accuracy is often associated to high computational costs. To overcome this issue, one can generate suitable metamodels or reduced-order models. Particularly, model reduction techniques aim to reduce the complexity of the system of equations describing a certain physical phenomenon, like Proper Orthogonal Decomposition or Proper Generalized Decomposition techniques [1]. Nonetheless, the main limitation of these methods is related to their intrusiveness and to the hypotheses that the solution must satisfy. Another limitation of model reduction techniques is related to the number of input parameters and observable outputs. Specifically, if the number of input variables is high, these strategies may fail to correctly predict the physical responses [1]. Metamodels are a sound alternative to decrease computational costs by preserving a sufficient level of accuracy. A metamodel can be seen as a generalisation of well-known fitting strategies used in computer aided design software to approximate/interpolate sets of data points through suitable explicit curves or surfaces, like non-uniform rational basis spline (NURBS) entities [2]. However, when considering MIMO systems, a higher-dimension entity (i.e., a hypersurface) capable of approximating the physical responses from a subset of dimension N to a subset of dimension M is required. To this end, the concept of NURBS hypersurface has been developed and used to generate suitable metamodels [3,4]. Specifically, in [4], a general problem formulation is proposed to generate metamodels based on NURBS entities,

which have been coupled to a general hybrid optimisation method to determine, simultaneously, the integer and the continuous variables involved in the definition of NURBS entity. In [4], the problem of generating a suitable metamodel based on NURBS entities is formulated as a constrained non-linear programming problem (CNLPP) defined over a space of changing dimension (the dimension of the space being related to the integer parameters of the NURBS entity), which requires a special genetic algorithm able to optimise, concurrently, the individuals and species. The goal of this study is to generalise the approach proposed in [4] by generating metamodels to approximate non-linear MIMO systems. The approach is tested on both global and local physical responses obtained via a high-fidelity finite element model. Three formulations of the CNLPP are considered, depending on the functional used to describe the error between the set of data points and the fitting hypersurface (average, maximum and p-norm). References: [1] F. Chinesta, R. Keunings and A. Leygue. The proper generalized decomposition for advanced numerical simulations: A primer. Springer Briefs in Applied Sciences and Technology, 2014. [2] L. Piegl and W. Tiller. The NURBS books. Springer-Verlag. 1997. [3] J. Steuben, J. Michopoulos, A. Iliopoulos, C. Turner, Inverse characterization of composite materials via surrogate modeling, Compos. Struct. 132 (2015) 694–708. [4] Y. Audoux, M. Montemurro, J. Pailhès. Non-Uniform Rational Basis Spline hyper-surfaces for metamodelling. Computer Methods in Applied Mechanics and Engineering, v. 364, art. num. 112918, 2020.

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abst. 1044
"Amarcord"
Thursday
September 1
12h00

A metamodel based on NURBS hypersurfaces to simulate the wire arc additive manufacturing process

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Additive Manufacturing (AM) processes are based on the "layer-by-layer" formulation, which allows producing parts overcoming the limitations of classic manufacturing processes [1]. AM processes may be grouped in three classes: powder bed system, powder feed system, and wire feed system (the last two are also known as direct energy deposition, DED) [1]. This study focuses on DED technologies, and particularly, on wire arc additive manufacturing (WAAM). This technology allows building large metal components with complex geometry by deposing weld beads with a high deposition rate [2]. However, the quality of produced parts is affected by thermal and mechanical phenomena occurring during the process, which are influenced by the parameters tuning the WAAM process. The understanding of the relationships between the physical phenomena and the parameters governing the WAAM process (together with the interaction between these parameters) represents a challenging task [1]. To this purpose, multi-fidelity finite element (FE) models have been adopted to analyse the different phenomena occurring in the WAAM process. Nonetheless, high-fidelity (HF) FE models are characterised by a high accuracy at the price of a high computational costs, whereas low-fidelity (LF) FE models are fast, but they provide results with limited accuracy [3]. In this context, metamodels can be used to build an efficient mathematical framework for capturing the behaviour of the WAAM process and to assess the influence of its main parameters on the shape and on the residual strain/stress fields within manufactured parts. Roughly speaking, a metamodel consists of defining a parametric explicit hypersurface capable of approximating (or interpolating) some data [3-5] without knowing the equations describing the physics of the problem at hand. Among the different existing metamodel techniques [3-5], Non-Uniform Rational Basis Splines (NURBS) entities offer many unique advantages [4] when compared to other metamodeling approaches [5]. In [4], surrogate models based

on NURBS hypersurfaces are coupled to a general hybrid optimisation method to optimise, simultaneously, the integer and the continuous variables involved in the definition of the NURBS entity. The goal is to minimise the distance between the set of target points (TPs) generated through HF FE models and the NURBS hypersurface approximating this set. The current research focus on the application of NURBS-based metamodel to WAAM process thermal simulation, which is non-linear and requires high computational costs. The goal is to approximate the temperature field (evaluated during the fabrication of the part) as a function of a subset of the main parameters governing the behaviour of the WAAM process. References: [1] Frazier, W.E. Metal Additive Manufacturing: A Review. J. of Materi Eng and Perform 23, 1917–1928 (2014). https://doi.org/10.1007/s11665-014-0958-z. [2] Akram Chergui, Frédéric Vignat, François Villeneuve, Finite Element Modeling and Validation of Metal Deposition in Wire Arc Additive Manufacturing, Advances on Mechanics, Design Engineering and Manufacturing III, 2021, Springer International Publishing, 61- 66, ISSN 978-3-030-70566-4. [3] Lening Wang, Xiaoyu Chen, Sungku Kang, Xinwei Deng, Ran Jin, Meta-modeling of high-fidelity FEA simulation for efficient product and process design in additive manufacturing, Additive Manufacturing, Volume 35, 2020, ISSN 2214-8604, https://doi.org/10.1016/j.addma.2020.101211. [4] Yohann Audoux, Marco Montemurro, Jérôme Pailhès, Non-Uniform Rational Basis Spline hyper-surfaces for metamodelling, Computer Methods in Applied Mechanics and Engineering, Volume 364, 2020, ISSN 0045-7825, https://doi.org/10.1016/j.cma.2020.112918. [5] Sophie Baillargeon, Le krigeage: revue de la théorie et application à l'interpolation spatiale de données de précipitations, PhD thesis, Université Laval, Quebec, Avril 2005, URL https://corpus.ulaval.ca/jspui/handle/20.500.11794/18036

A Neural Network-based Approach for Strain Gradient Nanoplates

abst. 1045
"Amarcord"
Thursday
September 1
12h45

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Over the past years, a growing interest has been devoted to the field of nanomaterials and nanostructures. The applications are manifold and include microelectromechanical (MEMS) and nanoelectromechanical (NEMS) systems, widely employed in the mechanical, aerospace and electronic fields. Accordingly, the number of studies on theories and methods for the analysis of nanoplates has seen a drastic surge in the recent scientific literature. On one hand, different models have been proposed for capturing the long-range effects that characterize the structural response at nano level - early works on strain gradient theory can be found in [1,2]. On the other hand, solutions based on analytical methods [3] - Navier, Levy - and numerical ones [4] - Finite Element, meshless - have been proposed to derive reference results, investigate the effects of the model's parameters and assess the structural response. Aside of this, an emerging trend regards the application of Physics Informed Neural Networks (PINNs) as an effective mean for solving differential problems, including those of structural mechanics. PINNs are an inherently meshless strategy relying upon the powerful framework offered by modern neural networks. Recently, the authors have proposed the application of PINNs to study composite structures at macro scale level [5]. In this work, the PINN framework is extended and applied, for the first time, to the static analysis of nanoplates. Specifically, the differential equations based on nonlocal strain gradient theory are solved by means of PINNs. Training is conducted under the paradigm of Extreme Learning Machine (ELM). The study illustrates the potential of this new meshless approach to handle nanoplate problems. Insights are provided into the features of the method, including the effect of different hyperparameters and network architectures. References: 1. E.C. Aifantis, On the role of gradients in the localization of deformation and fracture, 1992, International Journal of Engineering Science, 30(10), 1279-1299. 2. A.C. Eringen, On differential equations of nonlocal elasticity and solutions of screw dislocation and surface waves, 1983, Journal of Applied Physics, 54(9), 4703-4710. 3. B. Babu, B.P. Patel, Analytical solution for strain gradient elastic Kirchhoff rectangular plates under transverse static loading, 2019, European Journal of Mechanics-A/Solids, 73, 101-111. 4. M. Bacciocchi, N. Fantuzzi, A.J.M. Ferreira, Conforming and nonconforming laminated finite element Kirchhoff nanoplates in bending using strain gradient theory, 2020, Computers Structures, 239, 106322. 5. C.A. Yan, R. Vescovini and L. Dozio, A framework based on physics-informed neural networks and extreme learning for the analysis of composite structures, 2022, Computers Structures, 265, 106761.

abst. 1048
Repository

Effect of the load eccentricity of the compressed CFRP Z-columns in the weak post-critical state

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The study concerns short thin-walled Z-section columns made of CFRP laminate. The tested columns were subjected to compression, including an eccentric compression force relative to the gravity center of the cross section of the column. The boundary conditions applied in the study reflected articulated, simple support of the column's ends. The scope of the study included determination of the effect of eccentric load on the structure's buckling mode and critical load. The critical load of the real structure was determined using approximation method based on the post-critical equilibrium paths of the structure obtained in experimental tests. At the same time, a numerical analysis by the finite element method (FEM) was performed using the simulation software Abaqus®. The first step of the numerical analysis involved solving an eigenproblem to determine the buckling mode and to determine the bifurcation load of the ideal structure under axial and eccentric load. Next the critical load of the numerical structure was determined using approximation method based on the post-critical equilibrium paths of the structure obtained in the nonlinear analysis (FEM). The experimental results were used to verify the developed numerical models. The analysis enabled determination of the effect of eccentric load on the structure's buckling mode and critical load and the weak post-critical state, which is of vital importance for the design of thin-walled real structures that are coated with reinforcing thin-walled stiffeners. The project/research was financed in the framework of the project Lublin University of Technology-Regional Excellence Initiative, funded by the Polish Ministry of Science and Higher Education (contract no. 030/RID/2018/19).

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abst. 1050
"Amarcord"
Thursday
September 1
12h15

Determination of the critical energy release rate of FRP bars under mode I loading conditions: numerical approach

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The current trend in weight optimization led to the replacement of old, well-known materials with modern materials that provided superior properties. Composite materials might be an example. Many industries including chemical, automotive and civil engineering increasingly develop those materials for their own applications. Fibre-reinforced polymers (FRPs) have been widely used as an alternative material for steel, for instance, pultruded composite profiles, which find application in civil engineering, where growing attention is paid to the reinforcement bar for concrete members. Pultruded unidirectional smooth composite bars made of E-glass / epoxy with a diameter of 10 mm are the object of concern in this research. One of the most common failure mechanisms in composite materials is delamination, defined as debonding along adjoining layers. This phenomenon can be described using the cohesive law, the parameter that describes this phenomenon is the critical energy release rate. This value shows how the delamination propagates. A double cantilever beam allows determining the critical energy release rate for mode I loading conditions. Numerical analysis such as the cohesive zone model (CZM) is a useful tool for investigating such phenomena. Two sets of parameters need to be established to define cohesive behavior. The critical energy release rate and the initiation stresses are required. The interlaminar fracture energy toughness of the GFRP bar was investigated by the combination of the experimental and finite element method. The Double Cantilever Beam test was used to predict the interlaminar fracture toughness of this laminate and was carried out according to the ASTM D5528 standard. Modified beam theory with the correction factor taking into account different cross-sections (various moments of inertia) was applied to determine the fracture toughness. Then, finite element analysis was carried out based on the cohesive zone model (CZM) to numerically estimate the interlaminar fracture energy according to the load-displacement curve obtained from the DCB test. The approach shows that the interlaminar fracture toughness is equal to approximately 250 J/m2.

Validation of extension-bending and extension-twisting coupled laminates in elastic element

abst. 1052
Repository

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Analytical calculations were led on carbon fiber reinforced polymer (CFRP) laminates in asymmetrical configuration. Three types of configurations were investigated where Extension-Twisting and Extension-Bending couplings were used to get elastic element. Analysis was conducted according to classical laminate theory (CLT) toward the presence of elastic couplings. Components of matrices A, B, and D, as well as the parameters Dc and Bt were obtained using the Matlab software environment. The results showed that couplings between the extension and bending, as well as between the extension and twisting, were strongly dependent on specimen plies orientation. Moreover, additional analysis was performed on the influence of layers angle on the D11, D16, D12 and the D22 terms which are components of the Bt and Dc coefficients. The results indicated that angle of laying fibers around 45o-50o significantly amplifie the effects of elastic couplings.

Numerical modelling of impact on structural elements for automotive industry made with flax/PLA laminates

abst. 1057
"La Dolce Vita"
Wednesday
August 31
14h45

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This work aims to develop a numerical model based on the Finite Element Method to reproduce the impact behaviour of bumper beams made of green composites. The study of composite reinforced with natural fibres has received considerable attention in the last few years due to the growing concern about the environmental footprint of the industry. The green composites are characterized not only by the use of natural fibres as reinforcement but also by biodegradable matrices obtained from vegetal sources. Therefore, green composites are 100% biodegradable and have zero environmental footprints. In this work, bumper beams have been manufactured using flax/PLA laminates with different cross-section geometries. They were subjected to low-velocity impact tests using a drop-weight tower. The impact energy ranged from 5J to 73J, and the impact was carried out in a 3-point bending configuration. The contact force was recorded during the impact tests, and this record was integrated to measure displacement and absorbed energy histories. The impacted specimens were analysed using microcomputed tomography to estimate the extension of delaminated interfaces. The numerical model was developed in Abaqus/Explicit. In the model formulation, a constitutive equation based on a rheological model considering visco-elastoplastic behaviour of flax/PLA laminates, published in previous work [Rubio-López et al. 2016], and a user subroutine was developed to predict the failure of the green composite as a function of strain rate. Cohesive interfaces were also considered to reproduce the interlaminar failure. The numerical model predictions were compared with experimental results in terms of contact force history, the evolution of absorbed energy, and delamination extension showing excellent agreement. References: [1] Tanlak, N., Sonmez, F. O., Senaltun, M. (2015). Shape optimization of bumper beams under high-velocity impact loads. Engineering Structures, 95, 49-60. [2] Rubio-López, A., Hoang, T., Santiuste, C. (2016). Constitutive model to predict the viscoplastic behaviour of natural fibres based composites. Composite Structures, 155, 8-18. [3] Huber, T., Bickerton, S., Müssig, J., Pang, S., Staiger, M. P. (2013). Flexural and impact properties of all-cellulose composite

laminates. Composites science and technology, 88, 92-98. [4] Díaz-Álvarez, A., Jiao-Wang, L., Feng, C., Santiuste, C. (2020). Energy absorption and residual bending behavior of biocomposites bumper beams. Composite Structures, 245, 112343. [5] Estrada, R. G., Santiuste, C., Barbero, E. (2021). Failure maps of biocomposites mechanical joints reinforced with natural fibres. Composites Part C: Open Access, 5, 100159.

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abst. 1058
"La Dolce Vita"
Wednesday
August 31
15h00

Dynamic buckling estimation of a plate subjected to in-plane harmonic compressive load

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The investigation of the response of thin rectangular plates subjected to in-plane harmonic compressive load has been performed. The thin plates made of FRP laminates simply supported on edges have been considered and the influence of layers arrangements on dynamic responses has been tested. The well-known dynamic buckling criteria (e.g. Volmir, Budiansky-Hutchinson or Petry-Fahlbush) and the methods known from the stability of motion determination (eg., phase portraits, Poincare maps, Lyapunov exponents) have been employed. The applicability of considered methods for dynamic buckling assessment has been checked. The two different mentioned below methods for determining the plate in-time deflection have been used for checking the correctness and plausibility of the obtained results. The problem has been solved using the analitycal-numerical method and FEM. The analytical-numerical method consists of nonlinear differential equations of motions determination (i.e., the equation describing the deflection of the plate in time), which have been solved in a numerical way. In short, in the beginning, the differential equations of equilibrium for the considered plate were determined from Hamilton's Principle, then the system of ordinary differential equilibrium equations for the first and the second-order approximations was solved by a modified numerical transition matrix method in which the state vector of the final edge is derived from the state vector of the initial edge by numerical integration of the differential equations along the circumferential direction using the Runge-Kutta formulae by means of the Godunov orthogonalisation method, finally obtaining the Lagrange's equations describing the in-time plate deflection of the plate. The equation of motion was solved by the 4th Runge-Kutta method. The other way of the solution was numerical simulation using commercial software ANSYS based on the finite element method. The obtained results allowed us to assess the applicability of methods and criteria for dynamic buckling estimation and to check the influence of ply lay-ups in considered plates on its dynamic behaviour.

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abst. 1059
"La Dolce Vita"
Wednesday
August 31
15h15

Stability analysis of beam-type structures with composite cross-section considering coupled shear deformation effects

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This paper presents a shear deformable beam model for the nonlinear stability analysis of composite beam-type structures. Each wall of the cross-section is stacked in the cross-ply scheme. The incremental equilibrium equations are derived in the framework of an updated Lagrangian formulation. Hooke's law is assumed to be valid. The nonlinear displacement field of the composite cross-section accounts for the restrained warping and the large rotation effects. The shear deformation effects are included through Timoshenko's bending theory and modified Vlasov's torsion theory. Additional shear correction factors due to the bending-torsion coupling occurring at asymmetric cross-sections are introduced in the analysis. The accuracy and reliability of proposed numerical mode are verified on benchmark examples, and the obtained results confirm that it can be classified as a shear locking-free model.

Simulation-based separation of mixed material joints using X-ray computed tomography

abst. 1060
"La Dolce Vita"
Wednesday
August 31
15h30

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X-ray computed tomography (XCT) is a fast-growing and non-destructive measurement technology for industrial applications. However, measuring assemblies with XCT consisting of several materials is challenging due to beam hardening or metal artifacts. The distinction between closely spaced surfaces, as in commonly used mixed materials joints like clinched connections or rivets, may even become inconclusive and limits the dimensional measurability. An improving approach to distinguish such surfaces is to use an energy-sensitive detector optimized for the specific material combination. For such an optimization a suitable spectral sensitivity has to be determined first. Therefore, a study is conducted with a simulated clinched connection probe joining two sheets of aluminum and steel and using the surface deviation error for further evaluation. The resulting spectral sensitivity curves may be used to further improve the separation of mixed material joints with dimensional XCT measurements.

Thermal buckling analysis of thin-walled functionally graded closed section beams

abst. 1061
"La Dolce Vita"
Wednesday
August 31
15h45

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In this paper, thermal buckling analysis of closed thin-walled functionally graded (FG) beams based on Euler-Bernoulli-Vlasov theory is presented. The geometric numerical algorithm is developed using a 1D numerical model based on the application of the spatial finite element beam and UL (updated Lagrangian) incremental formulation. The cross-sectional displacement field includes the effects of warping torsion and large rotations. Material properties are assumed to vary continuously through the wall thickness based on power-law distribution. Three cases of the temperature distribution across the thickness of the cross-section walls are considered, which are uniform, linear and nonlinear. Numerical results are obtained for different closed thin-walled sections for various configurations such as boundary conditions, geometry, skin-core-skin ratios, and power-law index to investigate critical buckling temperatures and post-buckling responses. The accuracy and reliability of the beam model are verified by comparing it with previous research results and several benchmark examples.

Nonlinear finite element model for FGM porous circular/annular micro-plates under thermal and mechanical loads using modified couple stress-based third-order plate theory

abst. 1062
Repository

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A nonlinear finite element model for micro circular/annular plates under thermal and mechanical loadings is developed using a third order shear deformation theory. In the kinematic assumptions, the change of plate thickness and no tangential tractions on top and bottom surfaces are considered. A power-law distribution is utilized to account for variations of two constituents through plate thickness and three different types of porosity distributions are considered as a form of cosine functions. The strain gradient effect in micro scale structures is considered using the modified couple stress theory. The

effects of the material and porosity distributions, microstructure-dependency, the geometric nonlinearity, and various boundary conditions on the bending response of functionally graded porous circular/annular micro-plates are studied using the developed nonlinear finite element model.

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abst. 1064
"La Dolce Vita"
Wednesday
August 31
16h00

Semi-numerical Investigations of the Load Bearing Behavior of a Pin Joint Using a Material Structure Derived From Computed Tomography Scans

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Joining processes of fibre-reinforced thermoplastics (FRTP) change the internal material structure. The formation of the resultant material structure is driven by fibre reorientation processes on the fibre bundle scale and by the interaction of the fibre bundles and the matrix. These phenomena depend on the applied joining process and the process parameters (velocity, temperature field, heating area, pressure) as well as the used material and the tool design. The resultant material structure crucially influences the load bearing behaviour of the joint. Moreover, the load bearing behaviour and its predictability determine the joining technology's scope of application. In order to gain a deeper knowledge of the joint's material structure and to reliably predict the load bearing behaviour, it is necessary to simulate the loading behaviour. The structure simulation of composites often uses simplified numerical models. Because of these simplifications the results are often inaccurate and no information about detailed phenomena occuring in the material structure can be gained. Therefore, in this contribution the detailed material structure of a pin joint of aluminium (AL) and multi-layered unidirectional glass fibre (GF)/ polypropylene (PP) composite is investigated. The resultant material structure of the FRTP is determined by computed tomography (CT) analysis in terms of fibre orientation and fibre volume content (FVC) for a spatial volume element. These information are transferred to a Lagrangian elements of a Finite-Element-Mesh. In this case, the engineering constants for each element are determined with FVC-dependent functions based on experimental results. Subsequently, this material structure is used for a numerical analysis of shear tests. For the discretization of the composite and the metal pin two approaches are pursued: VOXEL-method and independent contour-based meshes. In the numerical analysis, the mesh refinement, the cluster of the FVC and also the pin geometry are varied. The comparison of the resultant numerical force-displacement curves to the experimental determined results indicates the necessary mesh discretization for prediction of the mechanical load bearing behaviour. Furthermore, the required discretization level of the numerical joining process simulation can be derived.

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abst. 1067
"La Dolce Vita"
Wednesday
August 31
16h15

Comparison of numerical analyses with Ex- and In-situ Investigations of Clinched Single-Lap Shear Test Specimens

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Force-displacement measurements and micrograph analyses are commonly used methods to validate numerical models of clinching processes. However, these methods often lead to resetting of elastic deformations and crack-closing after unloading. In contrast, the in-situ computed tomography (CT) can provide three-dimensional images of the clinch point under loading conditions. In this paper, the potential of the in-situ investigation of a single-lap shear test as validation method is analyzed. In the experiments, the shear test of two clinched aluminum sheets is interrupted at specific process steps in order to perform a CT scan. Then the specimen is unloaded and another CT scan is performed. Finally, the outer edges and the interface are determined in the digital image analysis and the deviations between ex- and in-situ methods as well as the numerical model are calculated.

Special Session- Advances in aeroelasticity and fluid-structures modeling (chaired by FD Marques, AJM Ferreira)

abst. 1065
"La Dolce Vita"
Thursday
September 1
12h45

Linear aeroelastic analysis of suspension bridges with second-order effects

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Aeroelastic instability induced by wind loads is one of the main concerns in the design of long-span suspension bridges. The increasing length of the main span - the recent 1915 Canakkale Bridge in Turkey established a new World record with its central span of 2023 m - and the consequent increase in flexibility makes these bridges highly sensitive to the wind action. Since the Tacoma Narrows Bridge failure in 1940, several semi-analytic, semi-empirical methods have been proposed to describe the aeroelastic behaviour of suspension bridges in order to predict the stability threshold. In this talk, an enhancement of a linear semi-analytic continuum model, which was previously proposed by two of the authors for the dynamic aeroelastic analysis of suspension bridges, will be presented. In agreement with the linearised deflection theory of suspension bridges, the kinematics of the bridge cross-section is described by means of two displacement parameters: the vertical deflection of the deck cross-section and its torsional rotation angle. The latter parameters are functions of the centroidal longitudinal coordinate of the bridge deck (coinciding with the elastic axis), allowing to describe the deck deformation by a one-dimensional structural model. The Scanlan's definition of the aeroelastic lift and moment by means of flutter derivatives is adopted, whereas the contribution of the mean steady drag force is embedded as a Prandtl-like second-order effect. The additional second-order terms introduced depict distributed vertical and torsional loads arising from a change in the geometric configuration of the system, thus, a form of geometric nonlinearity. A multi-degree-of-freedom model is thus obtained from the two partial integro-differential equations governing the flexural-torsional motion by Galerkin's method, defining the vertical and torsional kinematic parameters as weighted combinations of sinusoidal functions. An iterative procedure is introduced to carry out the eigenvalue analysis of the self-excited system for increasing wind speeds. The bridge modal frequencies are provided by the imaginary parts of the complex eigenvalues, whereas the real parts represent the modal damping factors. The variation of the eigenvalues with the wind load is investigated, as well as the evolution of the corresponding modal shapes, these latter being described by the real and imaginary components of the eigenvectors. The effect of the steady drag force on the flexural-torsional aeroelastic behaviour is highlighted and shown to be an affective coupling feature between the degrees of freedom. Divergence and flutter instabilities are identified by the appearance of eigenvalues having a non-negative real part and a zero or positive imaginary part, respectively. Numerical examples will be presented, providing a comparison of the results with those of the literature and of Finite Element analyses.

Special Session- Modelling of Constitutive Laws for Traditional and Innovative Building Materials (chaired by P Trovalusci)

Numerical simulation of fracture behaviour of the shot-earth 772 by means of a LDE numerical model

abst. 1021
"Amarcord"
Wednesday
August 31
14h00

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The shot-earth is an innovative and eco-friendly construction material, employed in the field of civil and industrial buildings, consisting of a predetermined mix of stabilised/unstabilised soil, sand and water, projected at high velocity onto a surface through a spraying nozzle. In particular, the shot-earth technique allows to both reduce the cement and sand content of about 50% with respect to conventional concrete techniques, and directly employ the excavation ground in the mixture [1]. Although shot-earth has been already used for non-structural applications, its mechanical and fracture properties need to be further investigated in order to extend its applicability to structural purposes. Therefore, the aim of the present research work is to study the fracture behaviour of a specific mixture of the shot-earth (named shot-earth 772), both from an experimental and a theoretical point of view. In particular, the shot-earth 772 mixture is characterised by the proportion soil: sand: cement equal to 7:7:2 (by volume), and a water content of about 3% (by volume). The fracture tests consist of three-point bending on single edge-notched specimens carried out according to both RILEM standards [2,3] and the Modified Two-Parameter Model (MTPM) [4]. From the experimental data, the material elastic modulus and fracture toughness are determined according to the MTPM formulation [4]. Moreover, the fracture behaviour of the shot-earth 772 is numerically evaluated by means of a Lattice Discrete Element Model (LDEM) implemented in the Ansys LS-DYNA finite element code [5]. The present LDEM consists of a set of masses joined by bar elements, characterised by a regular cubic arrangement. Moreover, the bars have a bilinear constitutive law, based on the Hillerborg model, which allows the breaking of the bar elements themselves, thus taking into account the degradation of the material. The failure mechanisms, damage locations, and load-deflection curves are numerically determined by employing such a model, and the results show a good agreement with the experimental findings. Keywords: Fracture behaviour, LDE numerical model, Modified Two-Parameter Model, shot-earth. REFERENCES: [1] Modern earth buildings. Materials, engineering, construction and applications. Edited by Hall M. R., Lindsay R., Krayenhoff M. Woodhead Publishing, Cambridge, UK, 2012. [2] RILEM Technical Committee, 50-FMC, Determination of the fracture energy of mortar and concrete by means of three-point bend test on notched beams, proposed RILEM draft recommendations. Mater Struct 1985;18:285–290. [3] RILEM Technical Committee, 89-FMT, Determination of fracture parameters (KsIC and CTODc) of plain concrete using three-point bend tests, proposed RILEM draft recommendations. Mater Struct 1990;23:457–460. [4] Vantadori S., Carpinteri A., Guo L.-P., Ronchei C., Zanichelli A., Synergy assessment of hybrid reinforcements in concrete. Composites Part B: Engineering, 2018; 147: 197-206. [5] Zanichelli A., Colpo A., Friedrich L., Iturrioz I., Carpinteri A., Vantadori S. A Novel Implementation of the LDEM in the Ansys LS-DYNA Finite Element Code. Materials, 2021; 14, 7792.

Numerical simulation of the shot-earth 772 under monotonic and cyclic loading: a macro-mechanical damage model

abst. 1022
"Amarcord"
Wednesday
August 31
14h15

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The aim of the present paper is to numerically simulate structural components made of the shot-earth 772 and subjected to monotonic and cyclic loading. The shot-earth 772 is an innovative and eco-friendly cementitious mixture, composed by 7 parts of excavated soil, 7 parts of aggregates and 2 parts of cement (by volume), and about 3% of water (by volume). The mixture stream is projected at high velocity onto a surface, where the impact compacts the material [1]. Although remarkable chemical-physical properties characterise the shot-earth [2], its behaviour under static and cyclic loading needs to be further investigated for widespread diffusion of such a material in the construction industry. Therefore, an extensive experimental campaign is carried out on the shot-earth 772 specimens subjected to both static (compressive and bending) and cyclic (bending) loading. The obtained results, in terms of compressive and flexural strengths, and S-N curves, are used to calibrate a macro-mechanical damage model, implemented in a FE code [3]. In the hypothesis of a homogeneous material under constant amplitude cyclic loading, the fatigue behaviour is simulated by considering a reduction of its mechanical properties. For this purpose, a damage scalar parameter defined through the experimental S-N curves is introduced in the model. After the validation, the proposed model is applied to shot-earth structural components under complex loadings as those observed during service operations. Keywords: Cyclic loading, damage macro-mechanical model, shot-earth, S-N curves. REFERENCES: [1] Modern earth buildings. Materials, engineering, construction and applications. Edited by Hall M. R., Lindsay R., Krayenhoff M. Woodhead Publishing, Cambridge, UK, 2012. [2] Vantadori S, Żak A, Sadowski Ł, Ronchei C, Scorza D, Zanichelli A, Viviani M. Microstructural, chemical and physical characterisation of the shot-earth 772, Construction and Building Materials, 2022, submitted. [3] Scorza D. Mechanical modelling of short fibre-reinforced materials under static or cyclic loading. ISBN: 978-88-31482-00-4, 2020.

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abst. 1030
"**Amarcord**"
Wednesday
August 31
14h30

A new constitutive model for asphalt concrete materials in a mesoscale approach

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The mechanical behaviour of asphalts strictly depends on its internal structure, namely the location of bitumen and aggregate, together with voids. Therefore, a correct mechanical prediction of creep is achieved through a correct evaluation of the stress concentration among the inclusions and the voids within the domain of interest [1]. For this reason, the mechanical behaviour at medium-to-long-term of asphalt is studied in a 3D mesoscale approach, by explicitly modelling the composite material as a cluster of aggregates (the coarse fraction is considered, for computational reasons) and bitumen surrounding them. The random disposition of inclusions satisfies a given grading curve and a known volume fraction [2]. In agreement with recent viscoelastic formulation [3, 4] a new visco-elasto-plastic constitutive model has been developed, where the viscoelasticity is accounted for via a fractional formulation, i.e. through a parabolic-dashpot-based mechanical representation. The subsequent non-integer order differential model is treated with the Grunwald definition of fractional derivatives. Long term effects have been carried out under different monotonic and cyclic load conditions, based on some relevant experimental tests. The model itself accounts for a better understanding of the inclusions interaction within asphalt under different compressive external loads. References: [1] Murali Krishnan, J., Rajagopal, K.R. (2004). Thermodynamic framework for the constitutive modeling of asphalt concrete: Theory and applications. Journal of materials in Civil Engineering, 16(2), 155-166. [2] Mazzucco, G., Pomaro, B., Salomoni, V.A., Majorana, C.E. (2018). Numerical modelling of ellipsoidal inclusions. Construction and Building Materials, 167, 317-324. [3] Woldekidan, M.F., Huurman, M., Pronk, A.C. (2012). A modified HS model: Numerical applications in modeling the response of bituminous materials. Finite Elements in Analysis and Design, 53, 37-47. [4] Woldekidan, M.F., Huurman, M., Pronk, A.C. (2013). Linear and nonlinear viscoelastic analysis of bituminous mortar. Transportation research record, 2370(1), 53-62.

Numerical modelling of waves propagation in fully saturated anisotropic porous media

abst. 1031
"Amarcord"
Wednesday
August 31
14h45

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Predicting the waves propagation is still a challenging task for civil engineers and researchers from different fields such as structural mechanics, geology, geosciences but also biomechanics. An example could be the simulation of the seismic wave in a soil or rock medium in order to deduce the destructive forces acting on buildings and identify the suitable protective tools for safeguarding people's life. For this reason, a fully coupled multi-field model for the dynamic simulation of anisotropic porous materials is presented here. Following the mixture theory and the definition of the effective stress for anisotropic poro-elasticity, the multi-field formulation of the dynamic partial differential equations was developed. The numerical solution of the initial-boundary value coupled problem in space was obtained by using the well-known Finite Element Method (FEM) with inf-sup stable discretizations while, for temporal integration, two different strategies were followed: the classical monolithic implicit scheme and a semi explicit/implicit scheme coupled with a predictor/corrector algorithm [1]. The Bi-Conjugate Gradient Stabilized (Bi-CGStab) algorithm was used to solve the time-sequence of large sparse non-symmetric linear systems, with convergence accelerated by a suitable preconditioning technique [2], and was implemented in the three-dimensional finite element research code, GeoMatFem [3]. Dynamic analyses were performed, in order to test the computational efficiency of the developed numerical tool and to investigate the behavior of seismic waves in a fully saturated anisotropic soil. References: [1] De Marchi, N., Sun, W., Salomoni, V. (2020). Shear Wave Splitting and Polarization in Anisotropic Fluid-Infiltrating Porous Media: A Numerical Study. Materials, 13(21), 4988. [2] Ferronato, M., Franceschini, A., Janna, C., Castelletto, N., Tchelepi, H.A. (2019). A general preconditioning framework for coupled multi-physics problems with application to contact- and poro-mechanics. Journal of Computational Physics, 398, 108887. [3] De Marchi, N., Salomoni, V., and Spiezia, N. "effects of finite strains in fully coupled 3d geomechanical simulations." International Journal of Geomechanics, Vol.19(4) pages04019008 (2019).

FRCM for historical "wall beams" strengthening: experiments and computations

abst. 1034
"Amarcord"
Wednesday
August 31
16h15

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Heritage buildings preservation is not just about the structural safety, but it is necessarily related to the central themes of restoration, fruition and reuse of ancient buildings. Such topic requires an interdisciplinary design approach that involves - among the others - structural engineering, numerical modelling and architecture in order to address the challenges of contemporary times also in terms of interests of the stakeholders and heritage management. In this regard, the opportunities offered by natural F.R.C.M. (Fibre Reinforced Cementitious Matrix) composites, made of basaltic fibres and lime mortar, are analysed [1]. The main objective of the research is to expand the state of the art concerning the influence of such composites with reference to the applications on «in falso» masonries: load bearing walls built without a direct load path to the ground and acting like «wall beams» in case of collapse of the underlying masonry vaults. On this, an experimental campaign started in co-operation with the Kimia S.p.a., an Italian company with decades of experience in the field, in order

to make a comparative assessment about the influence of composites in the prevention of knockon collapses due to the aforementioned scenario, with the benefit of avoiding interventions on the vaults and without damaging unmovable artistic assets and valuable architectural features (e.g. precious pavings, mosaics, vaulted surfaces etc.). Furthermore, rather than the «canon» widespread intervention, an innovative application of F.R.C.M. is bands is proposed, aimed at interventions with reduced quantities of composite material and therefore improving its use in the heritage even more. Finally, a 3D Finite Element formulation for the case in question is analysed. The masonry is discretized by the Simplified Micro-Modelling through the modelling of a homogeneous unit, partitioned in bricks and mortar joints on the boundaries, characterized by a cohesive behaviour at the interfaces. Then, the model foresees the inclusion of interventions in composites, after a preliminary calibration through strategies that, relying on the experimental data and based on literature, allow to recreate the complex behaviour of F.R.C.M. composite materials [2, 3]. REFERENCES: [1] Chen, X. Zhang, Y. Huo, H. Wu, Z. Study of high tensile strength of natural continuous basalt fibers. Journal of Natural Fibers, Vol 17(2), 1-9, 2018. [2] Modeling of the Tensile Behavior FRCM Systems for Repair and Strengthening Interventions of Masonry Structures, Frontiers in Built Environment, Vol 6, 51, 2020. [3] Minafò, G. Oddo, M.C. La Mendola, L. Formulation of a truss element for modelling the tensile response of FRCM strips. Construction and Building Materials, 125576, 2021.

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abst. 1039
"Amarcord"
Wednesday
August 31
15h45

Shear characterization of periodic masonry through numerical and experimental validations at the elementary scale

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The literature on periodic masonry provides us with various identification models, with promising numerical validations. However, experimental investigations essential for the practical application of these models are limited. They pose challenges in terms of geometries, unmanageable specimen scales, and even complex boundary conditions, that are nearly impossible to be replicated numerically without the aid of large approximations. Especially, when it comes to experimental validation of strengthened masonry, the number of specimens that are needed for a holistic mechanical characterization is not practically feasible. The current research aims at addressing this limitation, by adopting a masonry specimen at the scale closest to the elementary characteristic cell - the Triplet. Being the smallest scale at which the texture and defining characteristics of a periodic masonry can be sufficiently represented, two masonry configurations, the running bond triplet and the stack bond triplet were realized by introducing vertical mortar joints (head joints) to the standard triplet. The research also adopts a cosserat continuum identification model, which when compared to the classical model gives an opportunity to take into consideration smaller specimen-unit ratios, the micro-deformations, and micro-rotations. In addition to this, FEM models were built and analyzed.The experimental campaign conducted has its focus on shear characterization, where the triplets were tested in a pure shear setup. In addition to the new configurations, the standard triplet was also subjected to these shear stresses, which formed a benchmark for comparisons. The outcome of the experiments allowed the validation of the analytical and numerical models.

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abst. 1040
"Amarcord"
Wednesday
August 31
16h00

Predictive models for the ultimate tensile and compressive strengths of HPFRC/UHPFRC

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Smart fiber reinforced cementitious composites, like HPFRC and UHPFRC, are today widely applied in the field of the rehabilitation of concrete structures. However, one of the main drawback of HPFRC/UHPFRC is that any modification of the matrix-fibers mix design, due to the market requirements, affects the mechanical properties of the hardened smart concrete, thus making useless tests performed on previous version of the smart material. For this purpose prediction strength models that link the properties of both fibers and matrix to the performances of the smart concrete are of great practical interest. This work presents a simple and effective model that predicts the compressive and tensile strengths of HPFRC as the fiber properties change. The predictive data obtained by the proposed model were compared to experimental data, showing a good agreement.

Experimental characterization and predictive modeling of the flexural behavior of HPFRC/UHPFRC beams

abst. 1041
"Amarcord"
Wednesday
August 31
15h00

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The high manufacturing costs of UHPFRC applications together with time-consuming tests requested for the characterization and control quality restrict a wider application of this kind of smart material in the field of the rehabilitation of concrete structures. For this purpose, predictive strength models are useful to reduce this kind of and, at the same time, optimize the amount of compounds in the mixture according to the design requirements, for example by detecting the minimal dosage of fibers necessary to attain the design tensile strength. At the present, no predictive strength models suitable for HPFRC/UHPFRC are available. This work proposes a model able to predict the mechanical response of HPFRC/UHPFRC for any change of matrix and fiber properties. The reliability of the proposed model was confirmed from a large experimental investigation performed on smart concrete mixes.

Circumferential buckling of thick-wall hyperelastic tubes under radial pressure

abst. 1051
"Amarcord"
Wednesday
August 31
15h15

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Nonlinear elastic tubes in pressure are encountered in many fields of mechanics (pipes in pressure) and biomechanics (arteries, airways, urethral duct). In many cases soft materials and tissues are multi-layered in thickness, e.g. due to a circumferential growth process, and this is source of abnormal behaviour with regards to their mechanical stability. Under this condition, in fact, differential forms of instability are induced between the inner and outer edge of the tube [1]. Studies in this sense have involved growing spherical shells [2], and axially loaded growing pipes [3]. A recent analytic expression for the critical pressure for homogeneous thick tubes under radial pressure has been also derived by Papadakis [4]. A numerical model defined in the framework of hyperelastic materials and the theory of finite elasticity is developed to study the circumferential buckling of multi-layered tube systems. It is shown that a minimum occluding pressure is necessary to contrast buckling instability due to radial pressure, as well as to allow the reopening of the lumen area without occurrence of forms of instability. Specifically, the stabilizing bifurcation properties of the system under different scenarios are discussed in function of the geometric aspect of a two-layer tube configuration, and the occluding pressure. References: [1] Moulton, D.E., Goriely, A. (2011). Circumferential buckling instability of a growing cylindrical tube. J. Mech. Phys. Solids 59, 525–537. [2] Amar, M.B., Goriely, A. (2005). Growth and instability in elastic tissues. J. Mech. Phys. Solids 53, 2284–2319. [3] Vandiver, R., Goriely, A. (2009). Morpho-elasto-dynamics: the long-time dynamics of elastic growth. J. Biol. Dyn. 3(2), 180–195. [4] Papadakis, G. (2008). Buckling of thick cylindrical shells under external pressure: A new analytical expression for the critical load and comparison with elasticity solutions. Int. J. Solids Struct. 45, 5308–5321.

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abst. 1078
"Amarcord"
Wednesday
August 31
15h30

Composites with different material symmetries. Discrete-micropolar continuum description

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Particle composites include materials like ceramic, metal composites, poly-crystals, and masonry. Due to the presence of different heterogeneities (rigid or soft inclusions, voids, microcracks, etc.) whose size may have an important impact on their behaviour at the macroscopic scale, mechanical modelling is a challenging task.Non-local theories offer a solution to this problem while maintaining memory of the microstructure, especially the internal length. Differently to local classical models, non-local models (micropolar/Cosserat might be considered non-local continua of implicit type [1]) can account for internal lengths in the field equations, which are significant in many cases. The aim of this work is the mechanical characterization of anisotropic composites made of rigid particles and thin elastic interfaces at different level scale for investigating both statical and dynamical behaviour [2-3]. To find the anisotropic constitutive properties of those materials, a homogenization technique based on an energy equivalence criterion between a discrete model of the material and a continuum one is adopted [4]. Two continuum model descriptions, one micropolar and the other classical, are compared to the discrete system, assumed as benchmark. Different material symmetry classes, both centrosymmetric and non-centrosymmetric, are considered and the advantages of micropolar modelling are highlighted. Keywords: Micropolar Continua, Symmetry Class, Computational Multiscale. References: [1] Trovalusci, P., Molecular Approaches for Multifield Continua: Origins and Current Developments. In Multiscale Modeling of Complex Materials; T. Sadowski, P. Trovalusci, Eds.; Springer: Vienna, Austria, 2014; pp. 211–27, DOI:10.1007/978-3-7091-1812-2 _7; [2] Colatosti, M., Fantuzzi, N., Trovalusci, P. and Masiani, R., New insights on homogenization for hexagonal-shaped composites as Cosserat continua. Meccanica, 2021. https://doi.org/10.1007/s11012-021-01355-x; [3] Colatosti, M., Fantuzzi, N. and Trovalusci, P., Dynamic Characterization of Microstructured Materials Made of Hexagonal-Shape Particles with Elastic Interfaces. Nanomaterials 2021, 11, 1781, DOI: doi.org/10.3390/nano11071781; [4] Trovalusci, P. and Masiani, R., Material symmetries of micropolar continua equivalent to lattices, International Journal of Solids and Structures, 36(14), 2091-2108, 1999. DOI:10.1016/S0020-7683(98)00073-0

Special Session- New trends in nonlocal computational modelling (chaired by F Vieira, A Araujo)

Haar Wavelet Solution for Vibration Problem of Axially Graded Rayleigh-Bishop Nanorods

abst. 1001
"La Dolce Vita"
Thursday
September 1
14h15

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Axially graded nanorods are one of the interesting advanced functional nano-composites which have possible application areas like nano-wires. Continuum modeling of a graded structure in the length direction has issues in the solution approach which is analytical solutions could not be obtained. In the present work, vibration of axially graded Rayleigh-Bishop nanords will be studied. Eringen's Nonlocal Elasticity theory will be used in the modeling. Nonlocal parameter will be assumed in graded form in the problem formulation which is the novel essence of study. Solution process will be carried out with numerical Haar Wavelet and Higher Order Haar Wavelet methods. Results will be validated with using the approximate Ritz method. Effects of nonlocal and grading index parameters to the axially graded nanorod's dynamics will be investigated Convergence rates of the numerical methods will be compared and evaluated.

Biofilms as active sheets and filaments

abst. 1004
"La Dolce Vita"
Thursday
September 1
14h30

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Bacterial biofilms often spread forming sheets on surfaces and filaments in fluids. Such sheets and filaments undergo instabilities, like wrinkles and loops, frequently observed in elastic plates and threads. By modeling biofilms as active plates or threads, we are able to reproduce experimentally observed patterns. Biofilm deformation and spread can be described by nonlinear elastic or poroelastic models involving nonlocal terms representing cell activity and the interaction with the environment. Such terms are obtained averaging information provided by agent based models of bacterial behavior. We consider cellular automata and immersed boundary approaches to individual cell dynamics. Numerical simulations show that the models capture observed qualitative features such as accelerated spread and wrinkle formation in sheets or loops in filaments.

Peridynamics for fatigue crack evaluation in cylindrical test specimens

abst. 1005
Repository

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Reliable fatigue failure prediction of complex structures is still a challenging task for the numerical models based on the finite element method (FEM). The problem comes from the well-known FEM limitations in the case of discontinuities/singularities caused by the fatigue crack. Moreover, crack growth can be modelled in conventional FEM only if a pre-existing crack is defined. On the other side, the non-local continuum mechanics theory of peridynamics (PD), originally developed by Silling [1] and cast in terms of integral equation of motion, has proven its potential for numerical fatigue modelling. By the PD theory, fatigue crack initation, crack growth and failure phases can be modelled using the same model and no pre-existing crack is necessary. Yet, similar to classical fatigue theory based on SN curves

for crack initiation and Paris Law for crack growth, the PD fatigue modelling is also based on various empirical assumptions and parameters. An alternative approach to circumvent the strong empirical feature of the classical fatigue theory is the kinetic theory of fracture (KTF), developed by Coleman [2] and Zhurkov [3] already implemented in PD by Madenci et. al. [4]. Both conventional PD and KTF fatigue theories implemented in the PD framework are investigated in this study for high-cycle fatigue failure prediction in cylindrical test specimens. Fatigue crack initates in the model at location decided by probabilistic variation of the material properties, such as elastic modulus. Fatigue crack growth stage is calibrated in the model from crack growth rate data from Paris law in conjunction with an additional PD model of single notch specimen to measure the growing crack length. Numerical fatigue prediction results are in good agreement with experimental measurements. The proposed PD model and methodology can be used to evaluate the fatigue crack growth in 3D geometry structures. References: [1] S. A. Silling, Reformulation of elasticity theory for discontinuities and long-range forces, J. Mech. Phys. Solids. 48 (2000) 175–209. [2] B. Coleman, Time Dependence of Mechanical Breakdown Phenomena, J. Appl. Phys. 27 (1956) 862–866. [3] S. Zhurkov, Kinetic Concept of the Strength of Solids, Int. J. Fract. 1 (1965) 311–323. [4] E. Madenci, A. Barut, A. Yaghoobi, N. Phan, R.S. Fertig, Combined peridynamics and kinetic theory of fracture for fatigue failure of composites under constant and variable amplitude loading, Theor. Appl. Fract. Mech. 112 (2021) 102824.

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abst. 1018
"La Dolce Vita"
Thursday
September 1
15h15

The Micropolar Peridynamic Stress Tensor near Cracks in Quasibrittle Materials

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Quasibrittle structures subjected to loads that cause the formation and propagation of cracks exhibit a behavior where continuum mechanics is no longer applicable. In an effort to correct the shortcomings of continuum models, the bond-based peridynamic model and the state-based peridynamic model were proposed in 2000 and 2007 respectively. The micropolar peridynamic model improves the bond-based peridynamic by allowing moment densities in addition to force densities to interact among particles inside the material horizon, in addition, the micropolar peridynamic model is able to model materials with Poisson´s ratio different from 1/3 in two dimensions and 1/4 in two dimensions. With the definition of the Peridynamic stress tensor in 2007, the micropolar peridynamic stress tensor is defined and a number of benchmark problems are analyzed, where numerical and closed form solutions are found. Furthermore, relationships between the fracture energy and the maximum stretch are obtained as functions of the material horizon.

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abst. 1019
"La Dolce Vita"
Thursday
September 1
14h45

Design optimization of nanostructures

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Similarly, to macrostructures, design optimization of stiffness and strength properties, mass, cost, etc. is obviously important/critical also in the case of nanostructures. This research area is not yet well covered in various reasons like different limitations in manufacturing nanostructures, smaller effect of optimization, etc. For example, the optimal orientation angles for graphene sheet, thickness of graphene sheet cannot be handled like in the case of macro level. Current stud is focused on development of methods and tools for numerical analysis and design optimization of graphene and nanostructures, particularly maximization of the fundamental frequency values of the graphene and nanostructures.

The posed problem include mixed integer variables and traditional gradient based methods are not applicable. The evolutionary algorithms are developed considering the features of nonlocal structures.

Fracture analysis in piezoelectric ceramics using state-based peridynamics

abst. 1025
"La Dolce Vita"
Thursday
September 1
15h00

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In Peridynamics (PD) the natural appearance of cracks and their propagation is allowed due to the nonlocal character of this theory. The classical partial differential equations are reformulated into integro-differential equations, which also makes this theory easy to implement numerically using meshless point colocation schemes. PD original formulation has had several extensions to multiphysics formulations such as thermomechanics, electromechanics and others. The incorporation of different fields in the PD framework allows to exploit the capabilities of PD in more diverse domains. In this work we present a recently proposed piezoelectric PD model and use it to analyse fracture in piezoelectric structures. A non-ordinary state-based formulation is used and due to its inherent stability problems, the bond-associated correspondence is implemented. An implicit peridynamic approach is derived and used in order to expediently obtain linear systems of equations. This allows static and quasi-static analysis and evaluation of electromechanical fracture parameters in a more direct manner. Results illustrate the performance of these models and compare successfully against reference solutions.

A novel static and dynamic analysis of nanobeams made of nonlinear elastic materials

abst. 1038
Repository

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In the present study, static and dynamic analyses of a nanobeam made of materials with nonlinear elastic behavior have been studied. Euler-Bernoulli and Timoshenko beam theories have been used in existing research on the mechanical analysis of beams. However, in this research, we assumed the beam as a flat rectangular sheet, and we applied the first-order shear deformation theory to obtain the governing equations. Therefore, we expected the results to be more accurate than the beam theories studies. Also, the material from which the beam under analysis is made has nonlinear elastic behavior, and therefore Hooke's law could not be used to obtain stresses. Consequently, in this research, we developed a new theory of nonlinear elasticity and obtained the governing equations based on the theory proposed according to the energy method (Hamilton's principle). Also, considering the nanoscale analysis, we considered the effects of small-scale analysis by considering the theory of nonlocal elasticity. Combining the plane analysis of a beam with the nonlinear elastic behavior at the nanoscale is a category that has not been considered yet. Therefore, this study can be a pioneer in this field. The comparisons between the research results and studies done by other theories were made, and the efficiency of the proposed theory was proved. Finally, the essential factors influencing the research, such as size, boundary conditions, nonlinear elastic material, loading conditions, and external forces, were studied.

Longitudinal wave propagation in short fiber reinforced composite nanorods

abst. 1049
Repository

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In this study, longitudinal wave propagation analysis in short fiber reinforced composite nanorods is investigated based on the nonlocal elasticity theory. Short fiber reinforced composites have a wide range of applications due to their cheapness and ease of production. Short fibers are randomly distributed in the matrix material. These randomly oriented fibers in composite structures show isotropic material properties. The mechanical modeling of fiber-reinforced composite materials ranges from simple strength models to very complex multi-scale models. Based on the nonlocal elasticity theory, constitutive equation of a composite nanorod has been derived and the Halphin-Tsai equation is used to define the material properties of composite nanorods in the present study. Wave dispersion curves of short fiber reinforced composite nanorods are obtained for wave frequency, phase velocity and group velocity. The present study could be useful for the dynamic analysis of nanocomposite structures.

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abst. 1075
"La Dolce Vita"
Thursday
September 1
15h30

Thermomechanical analysis of modulus graded plates by using peridynamic theory

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The innovation of new functional materials are important tasks in the development of the engineering fields. Functionally graded materials (FGMs) have been widely used in many diverse industries owing to their desirable properties. FGMs are made of two or more material constituents mixed together to achieve gradually varying thermal and mechanical properties in the structures. This continuous nature in the materials enables to minimize the stress concentrations between two distinct materials. The idea of FGMs was originally introduced for nuclear reactors under thermal loads, but now its applications can be found in various disciplines. Thermomechanical loads cause inhomogeneous temperature distributions and high-stress concentrations which may lead to catastrophic failures in FGMS. Therefore, understanding the dynamic fracture behavior of FGMs under thermal loads is of vital importance. Many studies have been devoted to understanding the stress and deformation fields in the FGMS under thermal loads, but limited studies are available for the investigation of the dynamic fracture behavior of these structures. This study presents the thermomechanical analysis of one-dimensional FGMs by using PeriDynamic (PD) theory. PD theory reformulates the field governing equations in the Classical Continuum Mechanics (CCM) in terms of their nonlocal equivalence. This feature eliminates the spatial discontinuity-related issues encountered in the CCM. Thus, the governing equations of PD theory can be employed even if the material involves a discontinuity such as a crack. In this study, benchmark problems are considered to construct the validity of the proposed approach, and the influence of the material variation and loading/boundary conditions in one-dimensional FGMs under thermal loads is investigated in detail.

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abst. 1083
"La Dolce Vita"
Thursday
September 1
14h00

Elastoplastic behavior of microstructured composite as Cosserat continuum

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.The microstructure in materials can play an important role especially when its scale is comparable with the macro material's scale, thereby showing a non-local effect. In order to investigate the elastoplastic behavior of the microstructured composite materials and the scale effect of microstructures, this study takes an 'implicit' non-local model, i.e. Cosserat continuum, and develops elastoplastic Cosserat codes (also Cauchy codes for comparison) by considering Cosserat Von Mises yield criteria and the isotropic hardening rule. The results show that the developed Cosserat and Cauchy codes can both produce a clear elastoplastic behavior for the tension problem of a plate with a hole. The provided comparison of the solutions between two continuum shows the influence of micropolar properties on elastoplastic behavior and stress concentration near the hole. The plastic bands observed from the Cosserat continuum have wider distribution and smaller value compared with that from the Cauchy continuum. As the scale of microstructures decreases, the Cosserat continuum behaves closer to the Cauchy continuum. The maximum stress around the hole occurs at the same location and has the value of 0.3-0.4 MPa for both two continua. However, as the microstructures' scale increases the minimum stress increases and its location also changes, demonstrating a role of stress redistribution resulted from the Cosserat continuum. In addition, different composite materials show different elastoplastic behaviors due to their peculiar constitutive behaviors. Keywords: Material nonlinear; Elastoplasticity; Cosserat continuum; Scale effect

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Author Index