3D static thermo-magneto-electro-elastic analysis of flat and curved structures

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A Dual-Reciprocity Boundary Element Formulation for Two-Temperature Time-Fractional Thermoelastic Analysis of Layered Composite Shells with Cavities

abst. 1010
Repository

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A novel boundary element method (BEM) formulation is developed to investigate the two-temperature, time-fractional thermoelastic behavior of layered composite shells containing internal cavities under transient thermal shocks. The model integrates Caputo fractional heat conduction, representing nonlocal thermal memory, with a two-temperature framework that distinguishes conductive and thermodynamic temperatures, thereby capturing non-equilibrium heat transfer at microstructural scales. Each composite layer is characterized by distinct anisotropic thermal and elastic properties, and multi-domain coupling is rigorously enforced through interface continuity of temperature, heat flux, displacement, and traction. The governing equations are transformed into the Laplace domain and solved using dual-reciprocity BEM to eliminate domain integrals, enabling efficient and accurate simulation of complex geometries without volumetric meshing. Numerical inversion of the Laplace transform recovers the full transient response. Parametric results reveal that decreasing the fractional order α induces subdiffusive thermal waves and delays stress development, while increasing the two-temperature parameter bbb enhances thermal nonlocality and smooths transient gradients. Validation against analytical benchmarks confirms excellent accuracy, stability, and convergence of the formulation. The proposed approach provides a robust and computationally efficient tool for analyzing advanced composites and microstructured materials exhibiting fractional and non-equilibrium thermal behavior, offering new insight into the coupled thermomechanical response of functional layered systems subjected to high-rate thermal loading.

3D static thermo-magneto-electro-elastic analyis of flat and curved structures

abst. 1032
TIGELLIO
Wednesday
June 24
12h10

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Nowadays, thermo-magneto-electro-elastic coupling is an unexplored phenomenon for some classes of smart materials. These cutting-edge intelligent materials can be useful for the development of advanced aerostructures for the next generation of satellites, aircraft, and space vehicles. Their main innovations and advantages lie into functioning as sensors and actuators that respond to external thermal, magnetic, electric, or mechanical loads. To enable the use of these intelligent materials in the design of innovative aerostructures for next-generation space and aeronautical vehicles, the behaviour of thermo-magneto-electro-elastic structures must be deeply investigated. To understand the static behaviour of these intelligent smart structures, a 3D thermo-magneto-electro-elastic analytical model for multilayered spherical shells is proposed. Thermo-magneto-electro-elastic full coupling is included considering the six second-order differential equations for the thermo-magneto-electro-elastic problem as a unique set of equations. The six second-order differential equations consist of: the 3D equilibrium equations, the 3D divergence equation for the magnetic induction, the 3D divergence equation for the electric displacement and the 3D Fourier heat conduction. The use of the orthogonal mixed curvilinear reference system permits to investigate the behaviour of spherical shells, plates, cylinders and cylindrical panels. The set of second-order differential equations are solved in a closed-form solution taking into account the Navier harmonic forms in the in-plane directions and the exponential matrix method in the thickness direction. To correctly evaluate the 3D behaviour of considered structures, a layer wise approach is introduced by considering interlaminar continuity conditions on displacements, magnetic potential, electric potential, temperature, transverse shear and transverse normal stresses, transverse normal magnetic induction component, transverse normal electric displacement component and transverse normal heat flux component. Some preliminary results will be presented to validate the model. Then, new results for simply supported multilayered plates, cylinders, cylindrical panels and spherical shells will be proposed for different thickness ratio (from thick to thin structures). All

the possible involved effects for this smart material structures will be shown and discussed in terms of thermo-magneto-electro-elastic coupling, curvature of structures, material layers and lamination schemes and thickness layer values.

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abst. 1043
Repository

A Locking-Free Variationally Consistent Finite Element Formulation for Functionally Graded Timoshenko Curved Tapered Beams

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Functionally graded materials (FGMs) have attracted increasing interest thanks to their ability to overcome inherent limitations of laminated composites, leading to widespread use in advanced engineering applications. This has motivated extensive research on the modeling, analysis, and optimization of FGM beams, plates, and shells, with continuing efforts to develop simple, reliable and computationally efficient structural models. Complex geometries of many FGM components pose significant challenges to robust numerical modeling. While finite element methods have proven highly versatile, standard displacement-based formulations for curved Timoshenko beams typically suffer from shear-locking in slender configurations and membrane-locking when curvature increases. Common strategies, such as assembling short straight elements or resorting to hybrid-mixed formulations, either require many elements or are restricted largely to uniform cross-sections, with only limited extensions available for non-uniform geometries. This work proposes a simple, and effective finite element formulation for functionally graded Timoshenko curved tapered beams. The formulation is based on a complementary-energy-based variational setting in which the approximations satisfy all equilibrium equations in strong form, inherently eliminating both shear- and membrane-locking. The accuracy and robustness of the formulation are demonstrated through representative benchmark examples, and the obtained numerical results are thoroughly analyzed and discussed.

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abst. 1059
TIGELLIO
Wednesday
June 24
12h30

Validation of analytical models for adhesive-bonded single-lap joints using a physics-informed neural network

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Recent advances in computational resources and data science have led to the rapid growth of deep learning neural networks, a class of machine learning algorithms that has gained popularity due to its practical applicability across a wide range of science and engineering fields. One prominent and emerging application of deep learning is the solution of partial differential equations (PDEs). This has led to the development of physics-informed neural networks (PINNs), which incorporate physical laws to solve the differential equations governing specific scientific problems. As PINNs have proven to be an effective approach for solving PDEs, specialized algorithms are required that embed initial and boundary conditions directly into the cost function of artificial neural networks (ANNs) through automatic differentiation, ensuring consistency with the underlying physics. The validation of analytical models in engineering mechanics is commonly performed using experimental measurements or high-fidelity numerical simulations. However, closed-form analytical solutions are available only for a limited class of idealized problems. In most practical engineering applications, the governing physics is formulated in terms of PDEs, whose exact solutions are generally unattainable due to geometric complexity, nonlinear material behavior, and coupled boundary conditions. As a result, numerical discretization techniques, most notably the finite element method, are widely employed as reference solutions for model validation.