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Editorial

Special Issue on Advanced Theoretical and Computational Methods for Complex Materials and Structures

Francesco Tornabene * and Rossana Dimitri *

Department of Innovation Engineering, Università del Salento, Via per Monteroni, 73100 Lecce, Italy
* Correspondence: francesco.tornabene@unisalento.it (F.T.); rossana.dimitri@unisalento.it (R.D.)

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1. Introduction

The large use of composite materials and shell structural members with complex geometries in technologies related to various branches of engineering, has gained increased attention from scientists and engineers for the development of even more refined approaches, to investigate their mechanical behavior. It is well known that composite materials are able to provide higher values of strength stiffness, and thermal properties, together with conferring reduced weight, which can affect the mechanical behavior of beams, plates, and shells, in terms of static response, vibrations, and buckling loads. At the same time, enhanced structures made of composite materials can feature internal length scales and non-local behaviors, with great sensitivity to different staking sequences, ply orientations, agglomeration of nanoparticles, volume fractions of constituents, and porosity levels, among others. In addition to fiber-reinforced composites and laminates, increased attention has been paid in literature to the study of innovative components such as functionally graded materials (FGMs), carbon nanotubes (CNTs), graphene nanoplatelets, and smart constituents. Some examples of smart applications involve large stroke smart actuators, piezoelectric sensors, shape memory alloys, magnetostrictive and electrostrictive materials, as well as auxetic components and angle-tow laminates. These constituents can be included in the lamination schemes of smart structures to control and monitor the vibrational behavior or the static deflection of several composites. The development of advanced theoretical and computational models for composite materials and structures is a subject of active research and this is explored here for different complex systems, including their static, dynamic, and buckling responses; fracture mechanics at different scales; as well as the adhesion, cohesion, and delamination of materials and interfaces.

2. Enhanced Theoretical and Computational Formulations

In a context where an increased theoretical/computational demand is usually required to solve solid mechanics problems, this Special Issue has collected 11 papers on the application of high-performing computational strategies and enhanced theoretical formulations to solve different static and/or dynamic problems, for different engineering applications also in coupled conditions. A wide variety of examples and topics is considered, with highly useful insights both from a scientific and design perspective. More specifically, the first paper, authored by M.H. Jalaei, R. Dimitri and F. Tornabene, combines the Hamilton's variational principle and the Eringen's constitutive model to study the dynamic stability of orthotropic temperature-dependent single-layered graphene sheets embedded in a temperature-dependent elastomeric medium and subjected to a biaxial oscillating loading in thermal environment [1]. These nanostructures are largely adopted as important components in various highly technological industries, such as nanoactuators, nanoresonators, nanosensors, and nanocomposites, such that non-classical continuum approaches are usually required for an accurate analysis of results, especially for complicated coupled problems.

In the second work by K.J. Huang et al. [2], the authors develop an efficient theoretical approach to investigate the nonlocal and size-dependent (NLSD) effects on the dielectric response of plasmonic nanostructures that incorporate the spatially local, nonlocal, size and even analogous quantum-size responses of the material. On the other hand, unlike traditional engineering structural problems, the design of micro-electromechanical systems (MEMS) usually involves microstructures, novel materials, and extreme operating conditions, where multi-source uncertainties usually exist. In such a context, the work by Z. Huang et al. [3] develops an evidence–theory-based robustness optimization method for a robust design of MEMS, including a micro-force sensor, an image sensor, and a capacitive accelerometer of practical interest. Another application is represented by microfluidic devices, for which an analytical and practical method is efficiently proposed in the work by U. Tuzun [4] to study the Brownian motion in nanoparticle suspensions, as used in a variety of applications involving the transport of reagents and products to and from structured material surfaces. Among geotechnical engineering applications, the work authored by H. Sun and W. Sun [5] provides a useful finite element study for an effective measurement of safety and serviceability of existing metro tunnels during adjacent excavation, in lieu of centrifuge model tests, analytical or semi-analytical methods, or a more expensive in-situ monitoring. In the further work by Y. Zhu et al. [6], a quantitative evaluation of the solid displacement induced by a ground loss and shield machine mechanical effect is provided in metro tunnel constructions, based on an elastic half-space Mindlin model. The proportion of stratum displacement caused by each factor was quantitatively analyzed in this work, as a valid guidance for the stratum displacement calculation of shield tunneling in the future. A novel method is also proposed by X. Tan, H. Zhang et al. [7] to define the three-dimensional Greenfield stratum movements caused by a shield tunnel construction, where an elastic half-space model of mirror-sink method is combined with a modified analytical approach to give a useful design tool for underground engineering constructions. An efficient numerical model is, instead, established by H. Sun et al. [8] to compute the tunnel deformation caused by a circular excavation, while adopting a hypoplasticity nonlinear constitutive model, able to account for path-and strain-dependent soil stiffnesses even at small strains. This method is useful for practical engineering soil-structure problems. The extensive use of composite materials and structures in many engineering applications with complex microstructure and manufacturing processes, requires a thorough attention to their mechanical performances, such as the structural deflection damage and load capacity [9–12], as well as the buckling and dynamic behavior [13–18], along with possible related uncertainties and stochastic variations. In this setting, the work authored by S. Zhang and X. Chen [19] provides a stochastic natural frequency analysis of typical composite structures with micro-scale (constituent-scale) and meso-scale (ply-scale) uncertainties, based on Monte-Carlo simulations and the response surface method. Another numerical model is proposed by S. Shahbazi et al. [20] to analyze the non-linear time-history of different structural members under the simultaneous effects of far- and near-field earthquakes, as useful for design computational tools. The last work, authored by A. Pavlovic, et al. [21] finally proposes a finite element study of the mechanical behavior of palletized products and polyethylene terephthalate bottles, partially filled with liquid under compressive stress conditions, as commonly occurs during a transportation process. In this last case, an accurate computational prediction of the transport-related integrity risks of bottles is desirable in order to avoid any kind of instability and damage phenomena within commercial products, with a clear economical repercussion.

3. Future Developments

Although this Special Issue has been closed, further developments on the theoretical and computational modeling of enhanced structures and composite materials are expected, including their static, dynamic, and buckling responses; fracture mechanics at different scales; as well as the adhesion, cohesion, and delamination of materials and interfaces, as useful for many industrial applications.

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