

Editorial

Special Issue “Mesh-Free and Finite Element-Based Methods for Structural Mechanics Applications”

Nicholas Fantuzzi 

Department of Civil, Chemical, Environmental, and Materials Engineering, University of Bologna, Viale del Risorgimento 2, 40136 Bologna, Italy; nicholas.fantuzzi@unibo.it

Received: 1 December 2020; Accepted: 2 December 2020; Published: 2 December 2020



Authors of the present Special Issue are gratefully acknowledged for writing papers of very high standard. Moreover, the reviewers are also acknowledged for providing punctual and detailed reviews that improved the original manuscripts. Finally, the Guest Editor would like to thank Professors Oliver Schütze and Gianluigi Rozza (Editors-in-Chief of the MCA) for the opportunity to publish this Special Issue and Everett Zhu for accurately managing the editorial process.

The present Special Issue aimed to present relevant and innovative research works in the field of numerical analysis. The problem of solving complex engineering problems has been always a major topic in all industrial fields, such as aerospace, civil and mechanical engineering. The use of numerical methods increased exponentially in the last few years due to modern computers in the field of structural mechanics. Moreover, a wide-range of numerical methods has been presented in the literature for solving such problems. Structural mechanics problems are dealt with by using partial differential systems of equations that might be solved by using the two main classes of methods: Domain-decomposition methods, or the so-called finite element methods, and mesh-free methods where no decomposition is carried out. Both methodologies discretize a partial differential system into a set of algebraic equations that can be easily solved by computer implementation. The aim of the present Special Issue was to present a collection of recent works on these themes and a comparison of the novel advancements of both worlds in structural mechanics applications.

This Special Issue collects 10 (ten) contributions from several countries and topics all within the field of numerical analysis. This Special Issue is devoted to scientists, mathematicians and engineers who are investigating recent developments in analysis and state-of-the-art techniques on mathematical applications in numerical analysis.

Mota et al. [1] presented an assessment on porous functionally graded plates. In particular, this work aimed to assess the influence of different porosity distribution approaches on the shear correction factor, used in the context of the first-order shear deformation theory, which in turn may introduce significant effects in a structure's behavior. To this purpose, porous functionally graded plates with varying composition through their thickness were carried out. The bending behavior of these plates was studied using the finite element method with two quadrilateral plate element models.

Bellora and Vescovini [2] discussed the implementation of a continuation technique for the analysis of nonlinear structural problems, which is capable of accounting for geometric and dissipative requirements. The present strategy can be applied for solving quasi-static problems, where nonlinearities can be due to geometric or material response. The present procedure has been demonstrated to be robust and able to trace the equilibrium path in structures characterized by complex responses. Several examples are presented and discussed for a combination of material and geometry nonlinearities.

The noise emitted by ships is one of the most important noises in the ocean, and propeller noise is one of the major components of ship noise. Ebrahimi et al. [3] carried out a calculation of propeller noise using numerical methods because evaluation of propeller noise in the laboratory, despite the

high accuracy and good reliability, has high costs and is very time-consuming. Software for numerical calculation of propeller noise, based on FW-H equations, was developed and the results were validated by experimental results.

Bacciocchi and Tarantino [4] presented a work on the study of natural frequencies of functionally graded orthotropic laminated plates using a finite element formulation. The main novelty of the research was the modeling of the reinforcing fibers of the orthotropic layers assuming a nonuniform distribution in the thickness direction. The Halpin–Tsai approach was employed to define the overall mechanical properties of the composite layers starting from the features of the two constituents (fiber and epoxy resin). The analyses were carried out in the theoretical framework provided by the first-order shear deformation theory (FSDT) for laminated thick plates. Nevertheless, the same approach was used to deal with the vibration analysis of thin plates, neglecting the shear stiffness of the structure. This objective was achieved by properly choosing the value of the shear correction factor, without any modification in the formulation.

Patel et al. [5] presented a trans-disciplinary, integrated approach that used computational mechanics experiments with a flow network strategy to gain fundamental insights into the stress flow of high-performance, lightweight, structured composites by investigating the rostrum of paddlefish. The evolution of the stress in the rostrum was formulated as a network flow problem, which was generated by extracting the node and connectivity information from the numerical model of the rostrum. The changing kinematics of the system was provided as input to the mathematical algorithm that computes the minimum cut of the flow network. The flow network approach was verified using two simple classical problems.

Uzun and Civalek [6] presented the free vibration behaviors of various embedded nanowires made of different materials. The investigation was carried out by using Eringen's nonlocal elasticity theory. Silicon carbide nanowire (SiCNW), silver nanowire (AgNW) and gold nanowire (AuNW) were modeled as Euler–Bernoulli nanobeams with various boundary conditions such as simply supported (S-S), clamped simply supported (C-S), clamped–clamped (C-C) and clamped-free (C-F). The interactions between nanowires and medium were simulated by the Winkler elastic foundation model. The Galerkin weighted residual method was applied to the governing equations to gain stiffness and mass matrices. In addition, the influence of temperature change on the vibrational responses of the nanowires were also pursued as a case study.

As required by regulations, finite element analysis can be used to investigate the behavior of joints that might be complex to design due to the presence of geometrical and material discontinuities. The static behavior of such problems is mesh dependent; therefore, these results must be calibrated by using laboratory tests or reference data. Once the finite element model is correctly setup, the same settings can be used to study joints for which no reference is available. The work by Ouakka and Fantuzzi [7] analyzed the static strength of reinforced T-joints and sheds light on the following aspects: shell elements are a valid alternative to solid modeling; the best combination of element type and mesh density for several configurations is shown; the ultimate static strength of joints can be predicted, as well as when mechanical properties are roughly introduced for some FE topologies.

Li and Chen [8] presented a new complex variable method for stress and displacement problems in a noncircular deep tunnel with certain given boundary conditions at infinity. In order to overcome the complex problems caused by noncircular geometric configurations and the multiply-connected region, a complex variable method and continuity boundary conditions were used to determine stress and displacement within the tunnel lining and within the surrounding rock. The coefficients in the conformal mapping function and stress functions were determined by the optimal design and complex variable method, respectively. The new method was validated by FLAC3D finite difference software through an example.

A Space-Time Finite Element Method (STFEM) is proposed by Dumont et al. [9] for the resolution of mechanical problems involving three dimensions in space and one in time. Special attention was paid to the nonseparation of the space and time variables because this kind of interpolation is well suited

to mesh adaptation. For that purpose, a 4D mesh generation was adopted for space-time remeshing. This original technique does not require coarse-to-fine and fine-to-coarse mesh-to-mesh transfer operators and does not increase the size of the linear systems to be solved, compared to traditional finite element methods. Computations were carried out in the context of the continuous Galerkin method. The present method was tested on linearized elastodynamics problems. The convergence and stability of the method were studied and compared with existing methods.

Finally, Moldenhauer [10] investigated two-dimensional differential equations of the kind $y' = f(x, y)$ that can be interpreted as a direction fields. Commercial finite element programs can be used for this integration task without additional programming, provided that these programs have options for the calculation of orthotropic heat conduction problems. The differential equation to be integrated with arbitrary boundaries was idealized as an finite element model with thermal 2D elements. Possibilities for application in the construction of fiber-reinforced plastics (FRP) arise, since fiber courses, which follow the local principal stress directions, make use of the superior stiffness and strength of the fibers.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Mota, A.F.; Loja, M.A.R.; Barbosa, J.I.; Rodrigues, J.A. Porous Functionally Graded Plates: An Assessment of the Influence of Shear Correction Factor on Static Behavior. *Math. Comput. Appl.* **2020**, *25*, 25.
2. Bellora, D.; Vescovini, R. A Continuation Procedure for the Quasi-Static Analysis of Materially and Geometrically Nonlinear Structural Problems. *Math. Comput. Appl.* **2019**, *24*, 94.
3. Ebrahimi, A.; Seif, M.S.; Nouri-Borujerdi, A. Hydrodynamic and Acoustic Performance Analysis of Marine Propellers by Combination of Panel Method and FW-H Equations. *Math. Comput. Appl.* **2019**, *24*, 81. [[CrossRef](#)]
4. Baccocchi, M.; Tarantino, A.M. Natural Frequency Analysis of Functionally Graded Orthotropic Cross-Ply Plates Based on the Finite Element Method. *Math. Comput. Appl.* **2019**, *24*, 52. [[CrossRef](#)]
5. Patel, R.; Riveros, G.; Thompson, D.; Perkins, E.; Hoover, J.J.; Peters, J.; Tordesillas, A. A Transdisciplinary Approach for Analyzing Stress Flow Patterns in Biostructures. *Math. Comput. Appl.* **2019**, *24*, 47. [[CrossRef](#)]
6. Uzun, B.; Civalek, O. Nonlocal FEM Formulation for Vibration Analysis of Nanowires on Elastic Matrix with Different Materials. *Math. Comput. Appl.* **2019**, *24*, 38. [[CrossRef](#)]
7. Ouakka, S.; Fantuzzi, N. Trustworthiness in Modeling Unreinforced and Reinforced T-Joints with Finite Elements. *Math. Comput. Appl.* **2019**, *24*, 27. [[CrossRef](#)]
8. Li, Y.; Chen, S. A Complex Variable Solution for Lining Stress and Deformation in a Non-Circular Deep Tunnel II Practical Application and Verification. *Math. Comput. Appl.* **2018**, *23*, 43. [[CrossRef](#)]
9. Dumont, S.; Jourdan, F.; Madani, T. 4D Remeshing Using a Space-Time Finite Element Method for Elastodynamics Problems. *Math. Comput. Appl.* **2018**, *23*, 29. [[CrossRef](#)]
10. Moldenhauer, H. Integration of Direction Fields with Standard Options in Finite Element Programs. *Math. Comput. Appl.* **2018**, *23*, 24. [[CrossRef](#)]



© 2020 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).