



## Editorial

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In this Special Issue we collect some selected and invited novel contributions that follows and extend are of the studies presented, at the '9th International Conference on Computational Methods' (ICCM2018), held in Rome, Italy in August 2018, with Professor Trovalusci as Chairman. The present Special Issue collects articles devoted to advanced material behavior modelled using fractional computational and mathematical models; high-performance Finite Element Method for materials and structural problems; Discrete Element Method for the application to mechanical and geomechanical problems; innovative lattice meta-materials within a computational linear and nonlinear dynamics framework; computational methods for nanocomposites, soft tissues and masonry structures.

Globally the whole issue collects twenty papers. Each contribution has undergone a standard review

process, and only papers which have attracted positive recommendations from at least two international referees, have been included. All articles are briefly introduced in the paragraphs below.

Blesgen and Amendola [1] present a mathematical derivation and validation of a numerical method for the solution of a finite-strain holonomic (rate-independent) Cosserat plasticity problem for materials. This works improved the present literature by considering parametrized micro-rotations and a novel two-pass preconditioning scheme for searching the energy-minimizing solutions based on the limited memory Broyden-Fletcher-Goldstein-Shanno quasi-Newton method. Numerical simulations compare the performance and efficiency of the present and previous algorithms which demonstrated that this numerical model can be effectively employed for studying the mechanical response of complex materials featuring large size effects.

Chiozzi and Benvenuti [2] investigate the capability of the recently proposed extended Virtual Element Method (X-VEM) to efficiently and accurately solve the problem of a cracked prismatic beam under pure torsion, mathematically described by the Poisson equation in terms of a scalar stress function. The X-VEM is a stabilized Galerkin formulation on arbitrary polygonal meshes derived from the VEM by augmenting the standard virtual element space with an additional contribution that consists of the product of virtual nodal basis functions with a

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suitable enrichment function. Convergence of the method on both quadrilateral and polygonal meshes for the cracked beam torsion problem is studied by means of numerical experiments. The results affirm the sound accuracy of the method and demonstrate a significantly improved convergence rate.

Burlon et al. [3] work on an improved version of the Analog Equation Method (AEM) which is suitable for non-linear dynamic analysis of time-fractional beams with discontinuities. Various sources of non-linearity and discontinuities are considered. The solution to the analog equation is represented by an integral form involving appropriate Green's functions of the generalized operator. As in the classical AEM formulation, the integral representation of the solution is then approximated dividing the beam in finite elements and considering a constant value of the fictitious load within every beam element. The solution is carried out by employing a Newmark integration scheme in conjunction with a G-1 algorithm to account for the fractional-derivative memory effects. Computational efficiency and accuracy is demonstrated in comparison with the classical AEM formulation.

Transrectal ultrasound (TRUS) guided needle biopsy is currently the clinical routine for diagnosis of prostate cancer. TRUS imaging is generally blurry and magnetic resonance imaging (MRI) of prostate is usually taken prior to the biopsy procedure to assist needle target planning. Cui and Liu [4] studied a novel geometric transformation method, based on the mechanics of materials, to facilitate the deformable registration of lesion sites from MRI to ultrasound imaging. Transformations of 3D volumes as well as 2D sections of prostate are carried out to evaluate the transformation performance with respect to different material properties and segmentation errors. Some practical issues on applying the method to clinical biopsy operations are discussed.

Superposition of Non-Ordinary State-based Peridynamics (NOSBPD) and Finite Element Method (FEM) for material failure simulations, including crack propagation and strain localization is developed by Sun et al. [5]. In this paper a peridynamic model capable of effectively treating strong and weak discontinuities is superimposed in the critical regions over an underlying finite element mesh placed over the entire problem domain. A rigorous variational framework of coupling local finite element and nonlocal peridynamics approximations that is free of blending

parameters is developed. Several numerical examples show the efficiency of the present superposition-based coupling approach.

Jabareen [6] develops a Finite Element formulation for modeling nearly incompressible materials at large strains using polygonal elements. The technique is a simplified version of the three-field mixed formulation that reduces the functional of the potential energy by expressing the measure of the volume change field in terms of the displacement field, where the latter is discretized using the Wachspress shape functions. The reduced mixed formulation eliminates the volumetric locking in nearly incompressible materials and enhances the computational efficiency as the static condensation is circumvented. A detailed implementation of the finite element formation is presented in this study. Applications are given that demonstrate the accuracy of the presented formulation with polygonal meshes.

Doagou-Rad and Mishnaevsky [7] present a study on the influencing parameters of the erosion behavior of the leading edges of novel wind turbine blade tips. The aim is to study the influence of the parameters controlling the erosion performance of the coatings under rain contacts. A systematic finite element simulation approach was implemented and three main groups of parameters namely environmental, design, and manufacturing were investigated. The conducted investigations reveal desirable coating material characteristics and a simple indicator to select materials which protect leading edges against rain erosion.

Pirrotta and Proppe [8] present a Line Element-Less Method which is an efficient approach for the approximate solution of Laplace equations on a general bidimensional domain. Introducing generalized harmonic polynomials as approximation functions, the line element-less method is extended to the inhomogeneous Helmholtz equation and to the eigenvalue problem for the Helmholtz equation. The obtained approximate solutions are critically discussed and advantages as well as limitations of the approach are pointed out.

In complex geodynamic processes occurring at convergent plate margins, rocks can be subducted at depth into the Earth experiencing metamorphism. A mineral inhomogeneity entrapped into another mineral, after exhumation to the Earth surface, will exhibit stress and strain fields different from those of the host because of the different thermoelastic properties.

Morganti et al. [9] propose a finite-element-based approach to determine the Eshelby and the relaxations tensors for any morphology of the inhomogeneity and for any crystallographic symmetry of the host. The proposed procedure can be directly applied in the framework of elastic geobarometry to estimate, on the basis of the Eshelby theory, the entrapment conditions (pressure and temperature) from the residual strain field measured in the inhomogeneity. The approach is validated against Eshelby analytical solutions available for spherical and ellipsoidal inclusions.

The numerical solution of the steady-state response of a uniform taut string on visco-elastic support under a concentrated transverse moving load is addressed by Froio et al. [10]. A local Discontinuous Least-Squares Finite Element Method (DLSFEM) formulation is developed within a complex-valued function space, to overcome numerical instabilities linked to high-velocity loads and handle far-field conditions through an effective Perfectly Matched Layer (PML) implementation. The present formulation joins a DLSFEM approach and a PML implementation, for solving the above-mentioned moving load problem. Numerical examples illustrate feasibility and accuracy of the method in reproducing the expected trends of solution and a priori error estimates.

Corre et al. [11] introduce a new elastoplastic beam model for reinforced concrete. Steel and concrete are both defined as elastoplastic materials. The beam model represents the concrete body whereas rebars are given a specific discretization. A Rankine criterion is used for concrete in both tension and compression, and a closed-form solution for the local projection of the trial stress on the yield surface is formulated. This extension of the kinematics leads to local accuracy and yields results comparable to 3D computations. The present reinforced concrete model is validated through a set of case studies.

In the work by Burlayenko and Sadowski [12] a 3D modelling of free vibrations and static response of Functionally Graded Material (FGM) sandwich plates is presented. A 3D brick graded finite element is programmed and incorporated into the code via the user-defined material subroutine UMAT in ABAQUS environment. The results of modal and static analyses are demonstrated for square metal-ceramic functionally graded simply supported plates with a power-law through-the-thickness variation of the volume fraction of the ceramic constituent. The through-the-thickness

distribution of effective material properties at a point are defined based on the Mori–Tanaka scheme. Exact values of displacements, stresses and natural frequencies available for FGM sandwich plates in the literature are used to verify the performance and estimate the accuracy of the developed 3D graded finite element.

Hu et al. [13] develop a systematic computational methodology to directly simulate the fracture of ship hull structure during ship stranding based on the meshfree Reproducing Kernel Particle Method (RKPM). The whole computational algorithm has four parts: The first part is establishing interpolation shape functions of RKPM; the second part is the meshfree computational algorithm for simulation of 3D crack propagation. The third part is a computational algorithm for detecting contact and calculating interaction force during ship stranding or grounding, and the last part is the constitutive modeling and update procedure during simulation for ship hull structure material. Validation is carried out through a large scale simulation of ship hull structure indentation test directly compared with the experimental test data.

Femoral risk factor (RF) for metastatic femurs based on finite element (FE) modelling and analysis has been presented by Falcinelli et al. [14]. 3D subject-specific FE models of right and left femurs of a real clinical case were generated from Computed Tomography (CT) images, and a heterogeneous Young's modulus distribution was mapped from CT to FE models. The femoral mechanical response associated to a compressive functional load is focused, by describing bone biphasic features through a linear poroelastic model that allows to account for the influence of pore pressure inhomogeneity induced by metastatic lesions. Comparisons with a standard linearly elastic formulation, related to a rough description of the metastatic tissue based on the sole grayscale analysis of CT images, are provided and discussed. The results highlighted the importance of including a refined description of metastasis in combination with a poroelastic formulation to identify critical regions of metastatic femurs prone to fracture.

Brunetti et al. [15] propose a mixed variational principle for deducing the generalized Marguerre–von Kármán equations (gMvK), governing the relatively large deflections of thin elastic shallow shells. These equations account for both non-flat stress-free

configurations of the shell and inelastic strains. The implementation involves C0 interior penalty methods within the UFL language provided by FEniCS. Numerical examples aim to discuss the role of the shallowness and the inelastic strain, comparing the results with the fully non-linear Naghdi shell model.

The behavior of human blood flowing in arteries is still an open topic for its multi-phase nature and heterogeneity. In large arterial vessels the well-known Hagen-Poiseuille law, which main assumption is that the blood is Newtonian, is considered acceptable. In small arterial vessels, instead, this law does not reproduce experimental results that show non-parabolic profiles of velocity across the vessel diameter. For capillary vessels the Casson model of fluids that is nonlinear is used in place the Newton law, resulting in nonlinear governing equations and difficulties in mathematical manipulation. For these reasons an alternative approach is proposed by Alotta et al. [16] which starts from the micro-mechanics of blood. The Hagen-Poiseuille model is enriched with long-range interactions that simulate the interactions of non-adjacent fluid volume elements due to the presence of red blood cells and other dispersed cells in the plasma. These nonlocal forces are defined as linearly dependent on the product of the volumes of the considered elements and on their relative velocity. It is shown that the fractional Hagen-Poiseuille law is able to reproduce experimentally measured profiles of velocity with a great accuracy, moreover as the dimension of the vessel increases, nonlocal forces become negligible and the proposed model reverts to the classical Hagen-Poiseuille model.

Luongo and Zulli [17] present a homogeneous shear beam model to address the free and forced dynamic behavior of a multi-story building. Discussion on the free dynamics is carried out, by highlighting the intriguing organization of the natural frequencies and modes in triplets, as functions of the wave-number. A case-study is analyzed to show the reliability of the homogeneous model, after comparing the outcomes with those provided by finite element procedures.

Tuna et al. [18] consider the numerical solution of a plate with a circular inclusion subjected to a uniform tensile stress obtained using Finite Element approach specifically formulated for non-classical and, both ‘implicit’/‘weak’ and ‘explicit’/‘strong’, non-local continua descriptions. The material parameters of

‘implicit’ non local model (Cosserat) are derived from a coarse-graining procedure while those of the ‘explicit’ are optimized according to stress concentration factors reported for infinite Cosserat plates. The advantages/disadvantages of both non-local models, with respect to the classical local model, are highlighted and discussed for the first time in the literature. The results, obtained by varying scale ratios and material parameter combinations for matrix-inclusion pair, reveal the significance of non-local description in the presence of geometric/material singularities.

A Convolutional Neural Network (CNN) has been proposed by Teng et al. [19] for damage detection of steel truss structures using two data sets: the modal strain energy or the combination of modal strain energy and dynamic response (acceleration). Damage in an element is described by its Young’s modulus reduction. Authors expect that a CNN combining strain energy and dynamic response improve the detection ability of a CNN only based on strain energy measures.

Finally, in the article by Song et al. [20] a bond-based Peridynamic model has been developed to simulate the coupled thermomechanical ice removal process in frozen structures. In the proposed numerical method, the influence of the deformation on the thermal states is accounted for. The ice is modeled as a brittle elastic material which takes into account the effects of temperature-dependent fracture toughness of ice. The proposed method is verified and validated by the de-icing system of an aluminum sheet covered with ice by comparing the results obtained from Peridynamic simulations and that obtained from Finite Element Method.

We hope that these research issues will provide opportunities to identify and discuss future developments in the theory and formulation for novel computational methods for materials and structures.

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2. Chiozzi A, Benvenuti E (2020) Extended virtual element method for the torsion problem of cracked prismatic beams. *Meccanica*
3. Burlon A, Failla G, Arena F (2020) An improved analog equation method for non-linear dynamic analysis of time-fractional beams with discontinuities. *Meccanica*
4. Cui F, Liu J (2020) Prostate deformable registration through geometric transformation by finite element method. *Meccanica*
5. Sun W, Fish J, Zhang G (2020) Superposition of Non-Ordinary State-based Peridynamics and Finite Element Method for Material Failure Simulations. *Meccanica*
6. Jabareen M (2020) A polygonal finite element formulation for modeling nearly incompressible materials. *Meccanica*
7. Doagou-Rad S, Mishnaevsky L (2020) Rain erosion of wind turbine blades: computational analysis of parameters controlling the surface degradation. *Meccanica*
8. Pirrotta A, Proppe C (2020) Extension of the line elementless method to dynamic problems. *Meccanica*
9. Morganti S, Mazzucchelli ML, Alvaro M, Reali A (2020) A numerical application of the Eshelby theory for geobarometry of non-ideal host-inclusion systems. *Meccanica*
10. Froio D, Rizzi E, Simoes FMF, Pinto da Costa A (2020) DLSFEM-PML formulation for the steady-state response of a taut string on visco-elastic support under moving load. *Meccanica*
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12. Burlayenko VN, Sadowski T (2020) Free vibrations and static analysis of functionally graded sandwich plates with three-dimensional finite elements. *Meccanica*
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18. Tuna Eroglu M, Leonetti L, Trovalusci P, Kirka M (2020) ‘Explicit’ and ‘implicit’ non-local continuous descriptions for a plate with circular inclusion in tension. *Meccanica*
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20. Song Y, Liu R, Li S, Kang Z, Zhang F (2020) Peridynamic modeling and simulation of coupled thermomechanical removal of ice from frozen structures. *Meccanica*

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