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EDITORIAL

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Editorial to Special Issue "Advanced non-linear modeling and numerical methods for smart materials and structures"

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Smart structures employ multifunctional materials, which take advantage of a wide spectrum of constitutive couplings ranging from thermomechanical to electro-magneto-mechanical to chemo-mechanical material behavior. Such smart multifunctional materials, which make use of the coupled constitutive equations, are typically embodied into load bearing structures as sensors or actuators. Diverse nonlinear effects, including physical and geometrical ones, are employed for both, smart materials and structures. These nonlinearities range from nonlinear material response and hysteresis phenomena, e.g., of ferroelectric materials and dielectric elastomers to thin-walled structures subjected to large deformations to the combination of both as, e.g., in finite strain problems of electro-active polymers. The 14 papers collected in the present special issue focus on the modeling of smart materials and structures within the framework of continuum theories of thermo-electromechanics and structural mechanics as well as on advanced methods used for the design and analysis of smart structures and the underlying coupled constitutive behavior.

The first four papers are concerned with continuum multi-physics modeling of smart materials. A general energy-based approach toward modeling of combined electrodynamic-thermomechanical problems is presented by Ricoeur and Wingen; a consistent formulation is obtained for the four-field problem and compared to a weighted residuals approach. Kozinov and Kuna discuss polycrystalline ferroelectric ceramics with defects like voids or inhomogeneities using three-dimensional finite elements with a phenomenological continuum mechanics constitutive model suggested by Landis. The configurational forces are computed for dielectric and piezoelectric inclusions in a postprocessing step. Nardinocchi and Teresi study smart growth in layered cylindrical structures for morphing of soft tubes by anisotropic growth, and the electrostatic charge distribution in single-walled carbon nanotubes is analyzed numerically by Lönnecke et al. In the latter paper different existing models are compared for three test cases: carbon nanotubes either charged with an overall charge or exposed to an external electric field, and a combination of these two cases.

The second group of seven papers puts a strong focus on the structural aspect of smart structures; in particular, on the modeling of slender and thin structures within the framework of structural mechanics of beams, plates, and shells. Actually four of the papers are concerned with accurate modeling of such structures without addressing the aspect of smart materials, as such theories are the foundation for the extension to composite structures with embodied smart materials. Hui et al. analyze the geometrically nonlinear response of sandwich beam structures employing a hierarchical one-dimensional modeling approach, Pagani, Azzara

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and Carrera study the geometrically nonlinear analysis and vibration of in-plane-loaded variable angle tow composite plates and shells, and a higher-order theory and closed form solutions for shells of revolution using the Carrera unified formulation are discussed in two papers by Carrera and Zozulya. Three papers are concerned with structural theories for smart structures with embodied smart materials. Kulikov and Plotnikova analyze the coupled thermoelectroelastic behavior of smart structures with temperature-dependent piezoelectric material properties using an exact geometry higher-order thermopiezoelectric solid-shell element based on the concept of sampling surfaces. The modified strain gradient theory is used by Zhou et al. to research the effect of nonlinear piezoelectricity and the size effect on the static deformation of a piezoelectric multilayer circular micro-diaphragm. The results of the paper provide a guideline for the study and design of piezoelectric micromachined ultrasonic transducers. A numerical framework for the simulation of electroactive paper is developed by Klassen and Klinkel using a scaled boundary plate formulation for isogeometric analysis. This framework is applicable to very thin structures and it captures the nonlinear ionic charge distribution in electroactive paper.

The last three papers are concerned with the design, optimization, and control of smart structures with integrated piezoelectric and dielectric elastomer transducers. The issue of noise reduction of laminated sandwich panels with a viscoelastic core and surface-bonded piezoelectric patches with purely resistive shunted damping networks is addressed in Cotrim, Araujo and Madeira. Optimal positions of the piezoelectric patches to reduce the radiated noise in the first five modes are found by solving a multi-objective optimization problem. Masoud and Maas present an energy-based approach to model the nonlinear dynamic behavior of soft material structures comprising dielectric elastomer transducers suspended with flexible elastic structures. The approach can be easily utilized to design and control soft transducer systems based on dielectric elastomer transducers, which is successfully illustrated for a buckled beam structure actuated by a multilayer dielectric elastomer transducer. The optimization of the dissipative properties of smart systems consisting of elastic, viscoelastic, and piezoelectric bodies with the electrodes connected to passive electric circuits is studied by Matveenko et al. These systems can also contain elements made of graphene composites, which are deformable solids with elastic or viscoelastic properties and which can simultaneously act as a single or several resistors; such a design is proven to ensure multimodal damping of the first three vibration modes in an example problem.

Last, but not least, the guest editors would like to thank the authors for publishing their contributions in this special issue and the reviewers for their contribution to the successful completion of the special issue. The guest editors would also like to express their sincere gratitude to the editors of Acta Mechanica, Hans Irschik, Alexander Belyaev, Thomas Böhlke, Christian Marchioli, Martin Ostoja-Starzewski, Yu Su and R. Eslami and to Silvia Schilgerius from Springer Wien for the opportunity to have this special issue published in Acta Mechanica.