SPECIAL ISSUE

Multiscale Computational Engineering in Israel

Guest Editors
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PREFACE

Multiscale computational methods in engineering have enjoyed vast development for more than three decades, which started in academia and has gradually penetrated engineering practice. This special volume is devoted to the multiscale computational research in Israel. Most of the authors that contributed to this volume (although not all of them) have lectured in one or more of the Israel Symposia on Computational Mechanics (ISCM) organized by the Israel Association for Computational Methods in Mechanics (IACMM, see www.iacmm.org.il). IACMM is affiliated with the International Association of Computational Mechanics (IACM) as well as with the European Community on Computational Methods in Applied Sciences (ECCOMAS), and constitutes a platform for promoting research in the area of computational mechanics conducted in industry and academia in Israel. Multiscale-related problems and methods find an important place in the computational activity in Israel; it should be noted that one of the pioneers of multiscale methods in the 1970s was Achi Brandt, from the Weizmann Institute of Science, who was the chief inventor of Multigrid. Today, Israel's basic research on multiscale methods is wide and as active as anywhere else. Moreover, challenging requirements largely based on advanced technologies cause Israeli industry to put multiscale-based approaches in the forefront of computational research.

This special volume is divided into two issues and comprises 14 selected papers dealing with various aspects of multiscale computational mechanics. These papers span a variety of application areas, including composite materials (Aboudi, Gilat, Ryvkin, Volokh) and smart materials (Rabinovitch), biomaterials (Yosibash), concrete (Gal), acoustics (Givoli, Harari), fluid mechanics with application to environmental engineering (Herszage), crystal growth (Brandon), dynamics of microstructures (Krylov), nanostructures (Hanein) and image processing (Yavneh). Some papers are focused on fundamental issues, whereas others tackle more specific engineering problems. The common thread among all these papers is the special importance and treatment of the multiscale aspect.

The first Special Issue includes papers dealing mainly with multiscale modeling of solids and in particular of composite materials—the field where multiscale approaches are arguably the most dominant today. The issue opens with the paper by *Volokh*, who proposes novel methods for modeling material failure based on the introduction of energy limiters in the constitutive description of solids and fluids. The paper analyzes the multiscale link between the atomic bond scale and the continuum elastic scale and provides several examples illustrating the im-

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plementation of the methodology. *Aboudi*, the author of the next paper, is the inventor of the solution technique for periodic composites referred to as the Method of Cells, which has been successfully used for micromechanical analysis of composites for more than a decade. In this paper, Aboudi reviews recent developments in finite-strain micromechanical analysis of multiphase composites undergoing large deformation. He considers materials with a large variety of constitutive relations and bases his analysis on the recently introduced High-Fidelity Generalized Method of Cells. *Ryvkin* considers periodic composites and other periodic structures, and reviews analytical and numerical approaches for their analysis based on the implementation of the Discrete Fourier Transform. This general approach allows the reduction of various large-scale problems to the single-cell problem. *Kushnir and Rabinovitch*'s paper is concerned with micromechanical analysis of smart structures, incorporating nonlinear piezoelectric-ferroelectric materials. The authors show that the implementation of the hierarchical multiscale approach, which includes the unit cell scale, the grain scale, the material point scale, the continuum scale and the structural element scale, establishes an efficient computational framework for analysis of this type. *Gilat and Aboudi* consider the buckling of micromechanical structures, which is one of the important failure modes encountered in periodic layered composites. On the basis of the homogenization technique, they present a finite deformation micromechanical analysis that is able to predict mechanical and thermal postbuckling of such structures. The paper by *Yosibash et al.* is concerned with the analysis of biomaterials and demonstrates the fact that multiscale methods find implementation in new engineering areas that, until recently, were almost completely based on empirical treatment. The authors use high-order finite element schemes combined with computer tomography data and micromechanics-based constitutive relations for the analysis of the human femur, and show that their multiscale models yield results that closely match experimental observations. The paper by *Gal et al.* which closes the first Special Issue, is an example of the practical side of multiscale analysis in solving engineering problems. The authors use the theory of homogenization for the development of a unit cell, which then serves as a building block in the analysis of concrete structures.

The second Special Issue is a collection of papers on the use of multiscale analysis in somewhat less traditional research areas. These include computational acoustics, dynamics of micro- and nanostructures, fluid mechanics and image processing. The issue opens with the paper of *Harari* reviewing the numerical difficulties that arise in the solution of acoustic wave problems, their origin, and various remedies devised to overcome them. The notions of resolution, subgrid-scale, and dispersion are of particular importance in this context, as shown in the paper. *Gur and Givoli* devise a computational scheme for the solution of acoustic wave problems related to noise pollution, which are of great importance in environmental engineering. The human hearing spectrum is very wide, spanning from 20 to 20,000 Hz, and the proposed method allows efficient calculations over this entire range of frequencies. The next two papers are devoted to the dynamics of nano- and microstructures. The paper by *Liba et al.*, invited from Hanein, proposes a dissipative particle-dynamics model for the vibration analysis of carbon nanotubes. This model bridges between continuum models, which disregard the atomistic structure, and computationally intensive models of molecular dynamics, and is found to be very effective. The paper by *Krylov* investigates a parametric instability of microscale beams actuated by a time-varying electrostatic force, based on the Lyapunov exponent criterion. In particular, the parametric stabilization considered in this work represents an example of the strong influence of the fast-scale excitation on the slow-scale behavior. The paper by *Rasin et al.*, invited from Brandon, investigates the influence of liquid-phase flow on the process of crystal growth from solution, from both the microscopic and macroscopic viewpoints. Models of different scales are devised that together provide a lot of insight into the growth process. *Herszage* considers the effects of turbulent wind blowing around a tall building, a complicated problem that has major importance in urban planning. A one-way nesting technique is developed for the computational solution of this problem, which involves the interaction between a small-scale model and an intermediate-scale model. *Holtzman-Gazit and Yavneh*'s paper closes this volume and is concerned with the importance of scale effects in image processing. The authors propose an improved patch-based algorithm for completing missing parts of images. They show that by applying this algorithm recursively, their approach leads to a multiscale framework that yields a dramatic improvement in the robustness of patch-based image completion.

In summary, this volume reflects the fact that multiscale phenomena and methods are today in the heart of computational engineering research. Without doubt, exciting developments in this field still await us in the coming years.

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