PREFACE: COMPUTATIONAL POROMECHANICS

This special issue of the *International Journal for Multiscale Computational Engineering* is dedicated to the field of computational poromechanics. We refer to the term poromechanics as a discipline that studies the coupled responses of multiphase materials that contain voids filled with one or multiple types of fluids. Materials fitting this description include many geological materials (e.g., sand, clay, and rock), live matters (e.g., bones, skins, periodontal ligament), and manufactured materials (e.g., concrete, diaper cores, and polymeric gels), among others. Inside a porous medium, the fluids in the voids may either be trapped inside the isolated pores or they may diffuse in the connected pore space. The multiple fluid constituents may also trigger chemical reactions among themselves or with the solid constituents. As a result, the deformation of the solid skeleton and the diffusion of the pore fluid are processes that strongly influence each other. This coupling effect is important for many engineering applications central to our daily lives. For instance, the buildup of the pore fluid pressure may lead to the fracture of the solid constituent, which in return allows hydro-carbon to be extracted, as in the case of hydraulic fracture. If an enormous amount of fluid is injected underground, the resultant pore pressure buildup may also reactivate previously stable faults due to the reduction of effective mean pressure. Meanwhile, the hydro-mechanical coupling effect has also been used to characterize hydraulic properties that are difficult to obtain otherwise. For instance, one may indirectly estimate the effective permeability of the porous medium by examining the stress history of a given load, such as bending load applied on a beam or indentation applied on a poro-elastic half-space. The aforementioned engineering applications are just a few examples in which the knowledge of poromechanics is crucial. In recent years, the advancement of computational resource and the availability of more accurate and detailed experimental data and *in situ* data has made it possible to develop models with a new level of sophistication and a justifiable complexity. Meanwhile, new engineering challenges, such as geological disposal of captured carbon dioxide, nuclear waste, and the development of horizontal wellbores for hydraulic fractures, and forensic geotechnical engineering have motivated a growing interest to incorporate numerical modeling as an integral part of engineering design and analysis.

This special issue provides a forum for presenting the state-of-the-art computational modeling for porous media. In the paper "Poromechanical cohesive surface element with elastoplasticity for modeling cracks and interfaces in fluid-saturated geomaterials," written by Regueiro, Wang, Sweetser, and Jensen, a multiphysical cohesive element is introduced to capture the multiphysical responses of fluid-saturated geomaterials. While the solid constitutive response of the cohesive surface element is governed by a traction-separation law, the effective hydraulic conductivity of the embedded strong discontinuity depends on the mechanical aperture, the distance between the upper and lower surfaces of the fracture. The numerical examples have shown that such a numerical treatment is useful for capturing the hydro-mechanical responses of existing cracks as well as interface between soil and foundation. In the cases where cracks or shear slip may propagate and the evolving crack geometry is not known *a priori*, a proper algorithm to predict the onset, propagation direction, and branching of the cracks without injecting mesh bias is essential. In the paper "Simulating fragmentation and fluid-induced fracture in disordered media using random finite-element meshes," by Bishop, Martinez, and Newell, a computational approach based on random close-packed Voronoi tessellations is introduced to simulate fracture initiation, propagation and coalescence. By using meshes discretized by polygon finite elements to minimize mesh bias, the authors have demonstrated that the proposed algorithm is able to replicate complex fluid patterns. Their results indicate that the simulations based on this new approach may achieve mesh convergence in a weak or distributed sense. At the reservoir or field scale, explicitly modeling each individual crack over a large volume becomes unfeasible due to high computational cost. The authors of the paper "Multiscale model for damage-fluid flow in fractured porous media," Wan and Eghbalian, attempt to provide closed-form solutions to predict the homogenized responses of fractured porous media distributed with strong discontinuities. By incorporating shape and orientation of the distributed cracks into the up-scaling process, macroscopic mechanical and hydraulic properties of the effective medium are obtained solely from those of the micro-constituents.

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No matter how sophisticated and comprehensive it is, a poromechanics model is not useful unless it can be properly calibrated and be able to deliver robust forward prediction. In the paper titled "Identifying material parameters for a micro-polar plasticity model via X-ray micro-CT images: Lessons learned from the curve-fitting exercises," the authors Wang, Sun, Salager, Na, and Khaddour explore this issue by analyzing the sensitivity of the material parameters and the length scale obtained from different inverse problems that incorporate different combination of specimen- and grain-scale measurements. The last contribution, "A component-based partial differential equation code build on Trilinos," demonstrates a highly efficient way to assemble PDE solvers based on a component-based design. The computational framework introduce great flexibility for modelers to introduce new techniques, such as automatic differentiation and stochastic finite element model. The paper includes a number of application examples and a wide range of boundary value problems assembled within this framework, including small and finite strain poromechanics under the isothermal and nonisothermal conditions. Both the advantages and drawbacks of this new computational approaches are discussed. Due to the direct involvement of the guest editor of these last two papers, the review process of these two contributions is handled by the editor-in-chief of IJMCE, Professor Jacob Fish.

The guest editor of this issue would like to take this opportunity to express his gratitude to the editor-in-chief Professor Jacob Fish, who offered help on handling the review process and approved this special issue. The guest editor is also thankful to the authors for their valuable contributions and to the reviewers for contributing their time and expertise, which significantly enrich the quality of the papers and help in maintaining the high publication standard of IJMCE. It is our hope that this volume will stimulate interest in the future development of multiscale models for porous media. We hope this collection of contributions will become the source of inspiration for the readers.

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