Computer Modeling in
Engineering & Sciences

Tech Science Press

DOI: 10.32604/cmes.2022.023238

EDITORIAL

Introduction to the Special Issue on Computational Mechanics of Granular Materials and its Engineering Applications

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Received: 15 April 2022 Accepted: 27 April 2022

1 Introduction

The purpose of this special issue "Computational Mechanics of Granular Materials and its Engineering Applications" is to introduce the latest research progress in computational mechanics and engineering applications of granular materials, with particular emphasis on the theoretical constructions of arbitrarily shaped particles, flow pattern transitions, bond-fracture model, neural network algorithm, CFD-DEM coupled method, and coarse-graining model, and to improve our understanding of the physical and mechanical properties of granular systems from the perspective of practical engineering applications.

2 Themes of This Special Collection

Granular materials exist widely in nature or industrial production, and form complex granular systems with structures. A granular system has complex mechanical properties of solid or liquid, and quasi-solid-liquid transition may occur under certain conditions. The discrete element method (DEM) was proposed in 1979 and has been shown to be a practical tool for studying the macro and mesoscopic behaviors of various granular materials. Although DEM has been successfully applied to the study of basic physical and mechanical properties of granular materials, there are still many challenges in computational granular mechanics, such as the construction of real particle morphology, flow pattern transition of granular materials, fluid-solid coupling calculations, multiscale computational model, fracture properties of granular materials and advanced neural network algorithms.

3 Invited Papers

A total of nine papers were selected through a robust peer-reviewed process. The nine papers, written by researchers from universities around the world, covered a wide range of topics in computational granular mechanics and engineering applications. Three papers investigated the fracture properties of granular materials based on the bond-fracture model; one paper analyzed the accuracy of neural network algorithms for predicting the constitutive model of granular materials; one paper developed a coarse-graining model and successfully applied it to biaxial compression tests of granular materials; one paper developed the coupling algorithm of computational fluid dynamics and discrete element methods; the remaining three papers focused on the dynamic behavior of granular materials under flow and impact.

Zhang et al. [1] proposed a densely arranged bonded particle model to analyze the crushing properties of granular materials. In this model, the problem of inner pore and equivalent diameter was solved by introducing reasonable corrections, and it could be used to simulate the evolution of mechanical properties under the compression process of granular materials.

Qu et al. [2] developed a constitutive model driven by a recurrent neural network (RNN), using long short-term memory (LSTM) and a gated recurrent unit (GRU) neural network to train the stress-strain model. The results showed that LSTM and GRU had similar predictive performances for constitutive models and could accurately predict the stress response of granular materials.

Zhang et al. [3] developed novel coarse-graining methods based on precise scaling laws, and proposed appropriate scaling rules and interaction laws for different particle sizes. Numerical simulations of biaxial compression tests with different scaling factors were performed using the exact scaling law, and the results showed that the accuracy of the coarse-grained system was acceptable.

Liang et al. [4] simulated the intrusion of differently shaped intruders into granular materials. The results showed that the friction coefficient between particles and the intruder shape significantly affected the drag force acting on the intruder. During the penetrating process, the friction between the particles and the intruders had little effect on the drag force.

Zhao et al. [5] used GJK and EPA theories to calculate the overlap between two convex polyhedral elements, and the mechanical response of a rockfill penetrated by a high-velocity projectile was simulated using DEM. Meanwhile, the impactor speed, penetration resistance, and deflection angle were counted to analyze the penetration resistance of granular materials.

Li et al. [6] developed computational fluid dynamics (CFD) and discrete element method (DEM) coupled models to simulate the flow characteristics of gas and seeds in a computing device, and studied the effects of the gas velocity and rotational speed on particle velocity and seeding efficiency. This CFD-DEM coupled model could be effectively used to predict the seeding performance.

Sun et al. [7] used EDEM software to simulate the flow characteristics of grains in a silo with a central decompression tube, and analyzed the effect of the central decompression tube on the granular flow pattern transition. The results showed that the grains in the silo with the central decompression tube were funnel flow, which was more conducive to the grain discharging process.

Zhu et al. [8] developed the bond-fracture spherical DEM model to calculate ice loads and structural mooring forces during the interaction of sea ice with structures, and the corresponding numerical results were compared with the FEM and experimental results. The results showed that the DEM model was suitable for simulating the ice loads and mooring forces of mooring structures.

Zhai et al. [9] developed a bond-fragmentation model based on dilated polyhedral elements. This model established virtual bonding surfaces and points, and considered the fracture criterion of tensile and shear strength. Meanwhile, this model could be used to analyze the crushing behavior of granular materials, which was of great significance to the study of the mechanical properties of crushed ice.

The above nine papers focused on the difficult issues of fundamental theories, numerical methods, and engineering applications in granular materials. The current research on computational mechanics of granular materials was discussed to promote the further development of computational granular mechanics and engineering applications.

Acknowledgement: Finally, I would like to thank Prof. Michael Zhuravkov of Belarusian State University, Prof. Zongyan Zhou of Monash University, and Prof. Yuntian Feng of Swansea University for their guidance on this special issue. And I would like to thank the Journal of CMES-Computer Modeling in Engineering & Sciences for its support of the research direction of computational granular mechanics.

Funding Statement: This editorial work was partially supported by the National Key Research and Development Program of China (Grant Nos. 2021YFA1500302, 2018YFA0605902) and the National Natural Science Foundation of China (Grant Nos. 20212024, 42176241).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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