processes

Editorial

Special Issue "Multiphase Flows and Particle Technology"

Xizhong Chen [1,*], Li Ge Wang [2] and Liping Li [2]

1 Department of Chemical Engineering, School of Chemistry and Chemical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
2 School of Qilu Transportation, Shandong University, Jinan 250061, China
* Correspondence: chenxizh@sjtu.edu.cn

Research into multiphase flow and particle technology is closely related and holds significant importance in various fields of engineering and scientific applications. As a subject, multiphase flow involves the study of complex fluid systems featuring interactions between different phases such as liquids, gases, or solids. Particle technology focuses on the behavior and kinetics of particles during processes like dispersion, mixing, transportation, and reactions. In-depth research into multiphase flow and particle technology is not only crucial for engineering practices including chemical engineering, energy, environment, materials, and construction, but also provides important clues for understanding numerous natural phenomena such as debris flow hazards and landslide disasters. Despite significant advancements in the research of multiphase flow and particle technology over the past few decades, there are still many challenges in need of solution. For instance, we require a deeper understanding of mass transfer, interaction mechanisms, flow field variations, and the dynamics of particle motion in multiphase flow. Furthermore, as new materials, processes, and research paradigms continuously emerge, there must be new studies that align with these advancements in the field of multiphase flow and particle technology. The aim of this Special Issue is to present research outcomes from academia and industry, focusing on the latest developments and challenges in the field of multiphase flow and particle technology. We have accepted a series of outstanding research papers covering various aspects of the subject, including fundamental theoretical studies, model development and optimization, and innovative engineering applications. Through these articles, we will delve into the importance of multiphase flow and particle technology, explore the current research status, and address the forefront issues for future advancements.

check for updates

Citation: Chen, X.; Wang, L.G.; Li, L. Special Issue "Multiphase Flows and Particle Technology". *Processes* **2023**, *11*, 2663. https://doi.org/10.3390/pr11092663

Received: 21 August 2023
Accepted: 29 August 2023
Published: 5 September 2023

Fundamental Theoretical Study

Fundamental theoretical research in multiphase flow and particle technology not only provides theoretical guidance for engineering practices but also promotes efficiency in industrial processes, contributing to sustainable development. Heat and mass transfer are key processes in multiphase flow and particle technology. In the fields of chemical engineering and energy, heat and mass transfer are crucial for optimizing reaction processes, improving energy utilization efficiency, and designing efficient heat exchange equipment. With accurate theories and models, we can enhance the control and efficiency of heat and mass transfer processes, leading to more sustainable and environmentally friendly industrial production. Michael Beckmann et al. [1] conducted a study into the heat and mass transfer of solid particles in one-dimensional oscillatory flows. By comparing experimental and simulated data, they derived elemental correlations for calculating Nusselt (Sherwood) numbers. The research presented quantitatively considers this issue across the entire ε-Re plane, taking into account the existing asymptotic models in different regions of the ε-Re plane.

Successfully applying small-scale laboratory research results to large-scale industrial production is a challenging task. Based on in-depth theoretical research, we can understand the correlations between multiphase flow and particle behavior at different scales and establish reliable numerical simulations and scaling laws. This enables engineers and researchers to better design and operate industrial processes, improve production efficiency, reduce energy consumption, and ensure product quality and consistency. Faraj M. Zaid et al. assessment by various authors [2] compared common scaling methods for gas–solid fluidized bed systems based on matching the primary dimensionless parameters. They verified the limitations of these methods and emphasized the importance of local measurements in fluidized beds for evaluating scaling relationships.

Model Development and Optimization

The development and optimization of models in multiphase flow and particle technology are of significant importance for understanding and predicting multiphase flow behavior, optimizing industrial processes, and driving innovation. By establishing accurate and reliable models, we can precisely describe and predict multiphase flow processes, providing guidance for engineering practices and optimizing industrial operations.

Firstly, model development and optimization allow for a profound understanding of the physical and chemical characteristics of multiphase flow systems. By studying the behavior of multiphase flow and particles in detail, we can establish mathematical models to describe their interactions and motion patterns. These models help to uncover key mechanisms such as mass transfer, heat transfer, and momentum transfer in complex multiphase flow, thereby enhancing our understanding of system behavior. Shaofeng Zhang et al. [3] used numerical simulation methods to study the flow field in a two-dimensional oscillatory fluidized bed. With a specific focus on the dynamic changes of particles, this research provided theoretical guidance for understanding and optimizing engineering practices in offshore floating platforms. Zejing Huang et al. [4] conducted tests on consolidated sand grains (CSG) with different water-to-cement ratios and volume ratios. They studied the gelation characteristics, sedimentation features, and diffusion processes of CSG in water, conducting a comparative analysis of the compressive strength and microscopic structure of CSG consolidation formed in air and water.

Secondly, model development and optimization can guide the optimization and design of industrial processes. By accurately describing models of multiphase flow, we can perform numerical simulations and optimizations to improve the efficiency and performance of industrial processes. Shaofeng Zhang et al. [5] integrated macroscopic calculation models for total pressure drop and dust removal efficiency into porous media models and used the source terms of conservation equations, resulting in a new mesoscale simulation approach. This approach was applied to granular bed filters (GBF) to easily obtain flow field data, providing references for GBF modeling. Tokheim et al. [6] used the CFD software Barracuda VR® to simulate a laboratory-scale cold-flow circulating fluidized bed classifier, comparing experimental results with CFD simulations to determine the most appropriate resistance model for accurately representing the real flow field. Beckmann et al. [7] calculated the relaxation effect of suspended rigid particles in one-dimensional oscillatory flow based on different resistance models and derived conditions in which relaxation can be neglected or where the resistance model can be replaced with a simpler configuration. Zhengtao Ren et al. [8] proposed a new method for automatically calculating the chord slope of the soil grain size distribution (PSD) curve and provided a comprehensive chart for checking the internal stability of sandy gravel. Its reliability was validated using experimental data, obtaining an index that can be used to assess internal stability.

Additionally, model development and optimization provide a foundation for innovation in multiphase flow and granular technology. Pengqing Zhou et al. [9] compared experimental data with CFD simulation results to validate the rationality of contact model parameters. They established a slurry injection model for saturated and water-bearing sand layers based on the VOF-DEM method and widely applied this model in research on factors affecting grouting processes. Guannan Liu et al. [10] developed a fractal permeability model considering the microstructure of coal fractures. By comparing their results with those of previous research, they verified the correctness of the model and analyzed the influence of micro-fracture structure on equivalent permeability. This provides a basis for understanding the microscopic mechanisms of macroscopic flow characteristics in coal seams and implementing effective production enhancement strategies under different geological structures. Chunyu Yang et al. [11] described the mechanical properties of grouted solids under seepage erosion conditions using an original method. They established a damage mechanics model for grouted solids under seepage erosion conditions and designed deteriorating experiments for grouted solids under seepage conditions. They studied the influence mechanism of permeating water pressure on the permeability of grouted solids and obtained the variation of the grouted solid's damage variable with permeating water pressure. Improving the deterioration theory under seepage conditions is significant for ensuring long-term safety in tunnel operation. Qing Jin et al. [12] studied the topological characteristics of sandstone flow networks based on complex network theory. This research is crucial for understanding the permeability of rock pores and their safety under external forces.

Innovative Engineering Applications

Multiphase flow and granular technology play significant roles in innovative engineering applications. The application of these technologies not only improves the efficiency and performance of existing engineering processes but also drives the development and implementation of new engineering applications.

The application of multiphase flow and granular technology in civil engineering is of great importance as it not only enhances construction efficiency but also adds the assurance of safe construction practices. Zhipeng Li et al. [13] obtained the creep parameters of the Burgers model based on experimental and testing results obtained from the Lianhua Tunnel project. They established a relationship between the parameters and ultimately developed a creep constitutive model that considers water content in fully weathered sandstone. This model provides theoretical support for the management of large deformation disasters in fully weathered sandy shale formations. Zhipeng Li et al. [14] proposed a quantitative design method for sand layer grouting and a reinforcement calculation method. The effectiveness of these methods was successfully verified in the Qingdao Metro Line 2 project.

The significance of multiphase flow and granular technology in reactor design and optimization lies in providing a thorough understanding of multiphase flow behavior during reaction processes, improving reactor performance, optimizing the preparation and distribution of particles, and considering safety and sustainability factors. The application of these technologies can provide guidance to engineers, enabling them to design more efficient, safer, and more sustainable reactor systems. Meiqiu Li et al. [15] designed three types of aerodynamic guide vanes and simulated the internal flow field using software. The reliability of the simulated numerical values was validated through material experiments. This research holds certain theoretical significance and provides guidance for the structural design of guide vanes in turbine air classifiers. Jingzhou Zhang et al. [16] systematically analyzed the effects of factors such as ideal tangential circles, particle injection, and initial gas mass flux on flow in corner-injected flows using experimental models and PIV (particle image velocimetry) technology. These research results provide theoretical support for the design of corner-fired furnaces.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Heidinger, S.; Unz, S.; Beckmann, M. Heat and Mass Transfer to Particles in One-Dimensional Oscillating Flows. *Processes* **2023**, *11*, 173. [CrossRef]
2. Zaid, F.M.; Al-Rubaye, H.; Aljuwaya, T.M.; Al-Dahhan, M.H. Assessment of the Dimensionless Groups-Based Scale-Up of Gas–Solid Fluidized Beds. *Processes* **2023**, *11*, 168. [CrossRef]
3. Huang, J.; Wang, R.; Xu, R.; Wu, B.; Wang, D.; Liu, Y.; Zhang, S. Numerical Simulation of Dynamic Variation Characteristics of Particles in a Rolling Fluidized Bed. *Processes* **2023**, *11*, 1696. [CrossRef]
4. Lin, R.; Jin, Q.; Zhang, Y.; Pan, G.; Qin, J.; Huang, Z. Gelation and Consolidation Characteristics of Cement-Sodium Silicate Grout within Water. *Processes* **2022**, *10*, 531. [CrossRef]

5. Liu, T.; Zhao, Z.; Wang, R.; Tang, M.; Wang, D.; Zhang, S. A Mesoscale Simulation Approach to Study the Flow Field in an Axial Granular Bed Filter. *Processes* **2023**, *11*, 1146. [CrossRef]
6. Jayarathna, C.K.; Balfe, M.; Moldestad, B.E.; Tokheim, L.-A. Comparison of Experimental Results from Operating a Novel Fluidized Bed Classifier with CFD Simulations Applying Different Drag Models and Model Validation. *Processes* **2022**, *10*, 1855. [CrossRef]
7. Heidinger, S.; Unz, S.; Beckmann, M. Simple Particle Relaxation Modeling in One-Dimensional Oscillating Flows. *Processes* **2022**, *10*, 1322. [CrossRef]
8. Lai, Y.; Bai, S.; Hou, J.; Zhou, Z.; Wu, Q.; Lv, X.; Yang, L.; Cao, W.; Ren, Z. A Synthetic Chart for Internal Stability Assessment of Soils Based on Soil PSD Curves. *Processes* **2022**, *10*, 807. [CrossRef]
9. Li, H.; Ji, X.; Zhou, P. Study on the Microscopic Mechanism of Grouting in Saturated Water-Bearing Sand Stratum Based on VOF-DEM Method. *Processes* **2022**, *10*, 1447. [CrossRef]
10. Xu, X.; Xu, L.; Yue, C.; Liu, G. A New Fractal Permeability Model Considering Tortuosity of Rock Fractures. *Processes* **2022**, *10*, 356. [CrossRef]
11. Liu, L.; Wang, H.; Zheng, S.; Dong, L.; Yu, Y.; Yang, C. Damage Model and Experimental Study of a Sand Grouting-Reinforced Body under Seepage. *Processes* **2022**, *10*, 256. [CrossRef]
12. Hu, Y.; Gu, J.; Liu, H.; Zhu, J.; Ye, D.; Liu, G.; Jin, Q. The Study of the Pore Structure Properties of Rocks Based on Complex Network Theory: Taking an Example of the Sandstone in the Tongnan Area in China. *Processes* **2022**, *10*, 211. [CrossRef]
13. Zhang, L.; Huang, C.; Li, Z.; Han, Z.; Weng, X.; Wang, L. Uniaxial Creep Test Analysis on Creep Characteristics of Fully Weathered Sandy Shale. *Processes* **2023**, *11*, 610. [CrossRef]
14. Li, Z.; Zhang, L.; Sun, D.; Zhang, Q.; Wang, D.; Wang, L. Quantitative Design Method for Grouting in Sand Layers: Practice in Qingdao Metro Line 2. *Processes* **2022**, *10*, 840. [CrossRef]
15. Zeng, Y.; Huang, B.; Qin, D.; Zhou, S.; Li, M. Numerical and Experiment Investigation on Novel Guide Vane Structures of Turbo Air Classifier. *Processes* **2022**, *10*, 844. [CrossRef]
16. Sun, W.; Zhong, W.; Zhang, J. Experimental Investigation on Turbulent Flow Deviation in a Gas-Particle Corner-Injected Flow. *Processes* **2021**, *9*, 2202. [CrossRef]